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This report reviews the components required in a regulatory impact analysis (RIA) of major federal regulations. Eight recent hazardous waste RIAs then are evaluated in terms of how well they meet these requirements. Twelve specific recommendations are provided for improving the usefulness of hazardous waste RIAs in the regulatory decision process.

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Improving RIAs: Suggestions for the Analysis of Hazardous Waste Regulations

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EXECUTIVE SUMMARY

ES.1 FRAMEWORK FOR ANALYSIS

Executive Order 12291, issued by President Reagan on February 17, 1981, requires that Federal agencies prepare a regulatory impact analysis (RIA) for their new major regulations. The intent of this order was to ensure that regulations would be subject to a rigorous benefit-cost analysis before they could be promulgated and that alternatives to regulation would be considered. As stated in the Environmental Protection Agency (EPA) Guidelines for Performing Regulatory Impact Analyses, "...by developing and organizing information, quantifying and monetizing benefits and costs to the extent possible, and determining distributional effects and economic impacts, the RIA should provide decisionmakers with a comprehensive assessment of the implications of alternative regulatory actions." This study explores how future hazardous waste RIAs could be performed so as to provide such comprehensive information for regulatory decisionmakers.

Figure ES-1 illustrates the eight main components described by EPA for its RIAs of hazardous waste regulations as well as other environmental rulings. A hazardous waste RIA starts with a brief description of the nature of the problem the proposed regulations are designed to correct as well as the Agency's statutory authority to impose such regulations. The current and proposed regulations and other regulatory alternatives to be analyzed are presented next. Major sources of data used in the analysis are then described. Supplementary data needed for each specific estimation model used in the analysis are presented later with the estimation models.

The analysis of impacts on products markets uses an economic model to determine how the new regulations will affect the prices and quantities of various goods. Impacts on employment level and plant closures are estimated as part of this analysis. The analysis of impacts on products markets provides inputs into two further components of the RIA: estimating the benefits due to the resulting changes in exposure to hazardous substances, and estimating the costs of the new regulation due to enforcement and compliance activities.

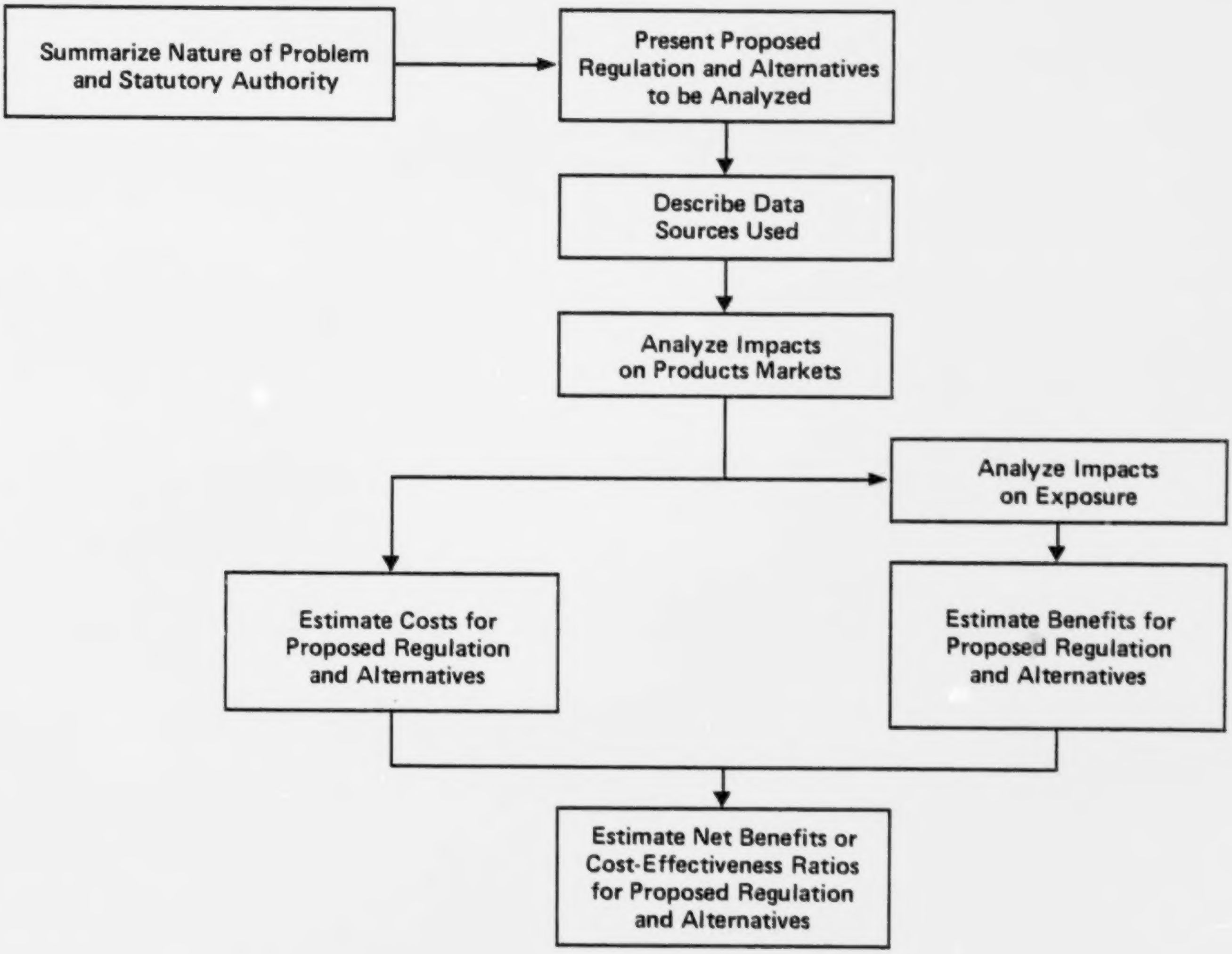
Summarize Nature of Problem and Statutory Authority
Present Proposed Regulation and Alternatives to be Analyzed
Describe Data Sources Used
Analyze Impacts on Products Markets
Analyze Impacts on Exposure
Estimate Costs for Proposed Regulation and Alternatives
Estimate Benefits for Proposed Regulation and Alternatives
Estimate Net Benefits or Cost-Effectiveness Ratios for Proposed Regulation and Alternatives

Figure ES-1. Flow chart for a hazardous waste RIA.

New regulations for managing hazardous wastes may reduce releases of the toxic substances into the environment in two ways: through the use of different disposal technologies or cleanup methods, and through reductions in the generation of hazardous wastes. The exposure analysis estimates the accompanying changes in environmental contamination and human exposure attributable to the new regulations. The results of the exposure analysis are used to estimate the benefits from regulatory action. Generally, the major benefit expected as a result of hazardous waste regulations is an improvement in health for persons at risk of exposure. Other benefits also may occur, such as fewer communities having to find alternative water supplies or engage in costly cleanup activities when aquifers become contaminated.

The promulgation of a regulation results in costs that include: increased production costs incurred by industry, increased product costs to consumers, consumer and producer surplus losses, dislocation costs from unemployment of labor and capital, and government costs from regulation. These costs are estimated using the results of the analysis of impacts on products markets. In some cases, a new regulation may result in reduced costs to producers and consumers in at least some market sectors.

The final component of the RIA compares the estimates of costs and benefits. This comparison should provide decisionmakers with a comprehensive assessment of the implications of alternative regulatory actions.

ES.2 COMPARATIVE ANALYSIS

Table ES-1 lists eight recent hazardous waste RIAs. Table ES-2 summarizes our comparative analysis of how well they satisfy the EPA guidelines for performing RIAs.

All of the RIAs include some quantitative analysis of the proposed regulation and all, except one, include some quantitative analysis of other regulatory alternatives under consideration. No RIA addresses alternatives to Federal regulation, and most do not discuss market-oriented regulatory alternatives and alternatives beyond current legislative scope.

All the RIAs use a variety of data sources, including some estimates based on informed judgment. Five of the eight perform sensitivity analysis on some or all of the variable values based on informed judgment. Half of the RIAs rely heavily on survey data to characterize the wastes, waste facilities, TABLE ES-1. REGULATORY IMPACT ANALYSES

Abbreviated title	Full reference
1. Contingency Plan:	Regulatory Impact Analysis of the Revisions to the National Oil and Hazardous Substances Pollution Contingency Plan. ICF, Inc. For U.S. EPA, Office of Emergency and Remedial Response. 1983.
2. Used Oil:	Regulatory Impact Analysis of Proposed Standards for the Management of Used Oil. Temple, Barker, and Sloane. For U.S. EPA, Economic Analysis Branch, Office of Solid Waste. November 1985.
3. Small-Quantity Generators:	Regulatory Analysis for Proposed Regulation Under RCRA for Small Quantity Generators of Hazardous Wastes. Industrial Economics. For U.S. EPA, Office of Solid Waste, June 1985.
4. Reportable Quantities:	Regulatory Impact Analysis of Reportable Quantity Adjustments Under Sections 102 and 103 of the Comprehensive Environmental Response, Compensation, and Liability Act. ICF, Inc. For U.S. EPA, Emergency Response Division, March 1985.
5. Incineration:	Supporting Documentation for the RCRA Incinerator Regulations. PEER Consultants, for U.S. EPA, Office of Solid Waste and Emergency Response, October 1984.
6. Land ban:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Hazardous Wastes. Industrial Economics, Inc. and ICF, Inc. For U.S. EPA, Office of Solid Waste. December 1985.
7. Dioxins:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Certain Dioxin-Containing Wastes. Industrial Economics, Inc. For U.S. EPA, Office of Solid Waste. Draft Final Report. January 1986.
8. Solvents:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Certain Solvent Wastes. Industrial Economics. For U.S. EPA, Office of Solid Waste. Draft Report. January 1986.

TABLE ES-2. SUMMARY OF COMPARATIVE ANALYSIS OF EIGHT RIAs

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Nature of problem	Releases of oil and hazardous substances to water and protection of environment when discharges do occur	Management of used oil	Disposal of hazardous waste from small-quantity generators	Releases of hazardous wastes to all environmental media from spills/accidents
Statutory authority	CERCLA	RCRA	RCRA	CERCLA
Regulatory alternatives	Some quantitative analysis for two alternative regulations	Quantitative analysis for four alternative regulations	Some quantitative analysis for six alternative regulations	Some quantitative analysis for two alternative regulations
Data sources used	Reporting data, industry data, estimates from EPA and other publications, and informed judgment; some sensitivity analysis	Industry data, estimates from EPA and other publications, and informed judgment	Reporting data, survey data, industry data, estimates from EPA and other publications, and informed judgment; some sensitivity analysis	Reporting data, survey data, case study data, industry data, estimates from EPA and other publications, and informed judgment; some sensitivity analysis
Impacts in products markets	Not estimated	Estimated percent change in prices and production levels	Not estimated because not expected to be significant	Not estimated because not expected to be significant
Exposure estimates	Number of people exposed in air, groundwater, and surface water; no exposure levels or durations	Number of people and steady-state average exposure in air, groundwater, and surface water; assumed 70-year exposure duration	Number of people and steady-state average exposure in air with 70-year exposure duration; number of people and moving average exposure in groundwater with ≤400 year total and 70-year individual exposure durations	None
Estimates of cancer and other harmful health effects	Discussed for typical chemicals but no quantitative estimates	Cancer cases for used oil use in 10 model facilities and national aggregates; exposure levels relative to RFD for noncarcinogens	Cancer and noncancer cases for disposal in landfills and to POTW	Discussed very briefly

(continued)

TABLE ES-2. SUMMARY OF COMPARATIVE ANALYSIS OF EIGHT RIAs (continued)

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Estimates of other harmful effects	None --briefly discussed	None - briefly discussed	None	None--briefly discussed
Estimates of costs	Engineering compliance costs and regulatory costs	Real resource costs from projected impacts on products markets	Engineering compliance costs and regulatory costs	Engineering compliance costs and regulatory costs
Cost-benefit comparisons in useful format	Useful table for proposed regulation, but comparison of alternative new regulations not included	Useful table presenting cost-effectiveness ratios for all alternatives	None given	Table for costs only for two alternative regulations

(continued)

TABLE ES-2. SUMMARY OF COMPARATIVE ANALYSIS OF EIGHT RIAs (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Nature of problem	Stack emissions from hazardous waste incinerators	Land-disposed wastes	Disposal of dioxin-containing wastes, especially land disposal	Disposal of solvent wastes, especially land disposal
Statutory authority	RCRA	RCRA	RCRA	RCRA
Regulatory alternatives	Some quantitative analysis for two alternative regulations	Quantitative analysis for four alternative regulations	Quantitative analysis for proposed regulation only	Quantitative analysis for two alternative regulations
Data sources used	Reporting data, survey data, case study data, industry data, estimates from EPA and other publications, and informed judgment; some sensitivity analysis	Survey data, estimates from EPA and other publications, and informed judgment; uncertainty analysis for exposure estimates	Reporting data, survey data, industry data, estimates from EPA and other publications, and informed judgment; uncertainty analysis for exposure estimates	Survey data, estimates from EPA and other publications, and informed judgments; some sensitivity analysis
Impacts in products markets	Not estimated	Not estimated	Not estimated	Not estimated
Exposure estimates	Number of people and steady-state exposure level in air; assumed 70-year exposure duration	Distribution of number of people and steady-state exposure levels in air, groundwater, and surface water; assumed 70-year exposure duration	Not presented	Number of people not estimated; average level and actual duration of exposure in air and groundwater; 70-year exposure duration assumed for health risk estimates
Estimates of cancer and other harmful health effects	Cancer cases for inhalation of air emissions from incinerators; potential to be above safe threshold for noncarcinogens	Cancer and noncancer cases for multiple disposal methods; weighted by severity factor	Cancer cases for multiple disposal methods; no estimates for noncarcinogens	Cancer cases for multiple disposal methods; exposure level relative to RFD for noncarcinogens
Estimates of other harmful effects	None	None--briefly discussed	None	None--briefly discussed

(continued)

TABLE ES-2. SUMMARY OF COMPARATIVE ANALYSIS OF EIGHT RIAs (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Estimates of costs	Engineering compliance costs	Engineering compliance costs	Engineering compliance costs	Engineering compliance costs
Cost-benefit comparisons in useful format	No; costs estimated for compliance with current regulations only: corresponding benefits not estimated	None given	No, discussion is inadequate	Compares percent change in costs to percent change in benefits. Does not look at absolute changes. Duration of disposal different for costs and benefits

and current management practices. The other half primarily use reporting data and previous EPA reports for their waste characterizations. Estimates from data provided in a report from a subcontractor or from a previous EPA report are used extensively as well as estimates from the research literature. Industry sources are used in many of the RIAs for data on current practices, costs, and resources available for cleanup programs.

All eight RIAs identify and discuss in some detail the markets that would be affected directly by the regulations. Impacts on market prices and output rates constitute "primary" economic impacts of regulations. Seven of the eight RIAs do not project these prices and output impacts at all. Of these seven, two explicitly state that price and output impacts are expected to be insignificant and are thus not projected. Others discuss price and output impacts qualitatively. The Used Oil RIA projects price and output impacts both in percentage and absolute terms.

"Secondary" market impacts include impacts on employment and impacts on capital utilization/industry growth. None of the eight RIAs quantitatively project employment impacts, though some do discuss possible impacts. Seven of the RIAs do not discuss potential impacts on existing or new capital at all. The Contingency Plan RIA does discuss possible changes in the cost of capital following regulation.

In the exposure analysis, the two CERCLA RIAs do not estimate actual release rates from the toxic chemical spills because the variability in size and chemical content was considered too great and the data too sparse to allow for adequate waste characterization. The RCRA RIAs all generate quantitative estimates of release rates from model waste streams to some or all of the media--air, groundwater, and surface water--for different waste disposal methods. Although the two CERCLA RIAs discuss releases to soil, none of the RCRA RIAs estimate exposures via soil contamination.

The number of persons exposed for each regulatory alternative is estimated in one CERCLA RIA (Contingency Plan) and all but one of the RCRA RIAs include estimates of the number of persons exposed. For the RCRA RIAs, estimates of exposure levels are obtained using release, fate, and transport models for air, groundwater, and surface water. Only two of these RIAs generate estimates for the duration of this exposure corresponding to a given duration and method of waste disposal. All of the RCRA RIAs assume lifetime exposure for the health risk estimates for all disposal methods. Plant and animal exposure is discussed in only three of the RIAs and other environmental impacts are discussed in four.

The two CERCLA RIAs discuss health benefits but perform no quantitative estimates. The six RCRA RIAs all generate quantitative estimates of cancer risks attributable to the toxic chemicals for various disposal methods. Five out of six of these RIAs also generate quantitative estimates of noncancer risks attributable to the toxic chemicals for various disposal methods. All these estimates are used to determine the reduction in risk with the regulation. None generates quantitative estimates of other harmful effects, although most discuss such effects and the Solvents RIA assumes exposure ceases when the water concentration is above the taste-odor threshold because people switch to alternative water supplies. The costs associated with switching are not estimated, however.

None of the RIAs explicitly estimates the timing of avoided cancer or noncancer cases relative to the time of exposure. In some cases the issue is discussed briefly. In these RIAs, the cancer cases are assumed to occur over the next 70 years or, in one RIA, over the next 400 years. None of the RIAs attempts to estimate or even discuss a dollar value that might be associated with a case of environmentally induced cancer or other adverse health effect. None of the RIAs attempts to discount the avoided cancer cases and only one even discusses the issue of discounting health benefits. In three of the RCRA RIAs the results of either sensitivity or uncertainty analyses for the estimates of avoided cancer risks are presented.

For the cost estimates, all but one of the RIAs use estimates of engineering compliance costs to estimate the real resource costs of the regulation. In the Used Oil RIA, the results of the products markets analysis are used to estimate the real resource costs of the regulation. None of the RIAs estimates costs of unemployment or displacement of capital. The three RIAs that estimate the regulatory costs are those in which such costs are likely to be significant.

Most of the RIAs present some comparison of the benefits and costs of new regulations. The Reportable Quantities RIA estimates net-monetized benefits but for changes in compliance costs only. The rest of the RIAs do not generate estimates of net-monetized benefits because health effects are not assigned a monetary value. However, in most cases some cost-effectiveness comparisons are attempted. These vary in their degree of quantification and in their clarity. In the Used Oil RIA, the ratio of annual dollar costs of the regulation to the annual number of avoided cancer cases is calculated. Annual avoided cancer cases are assumed equal to the avoided cancer cases for a single population cohort divided by 70. These ratios are used to compare regulatory alternatives. In the Contingency Plan RIA, although quantitative health effects are not generated, a useful tabular listing of benefits and costs is presented and discussed. The Small-Quantity Generators and Dioxins RIAs discuss the relationship between benefits and costs for different regulatory alternatives, but no attempt is made to quantify the relationship and no table is presented. The Solvents RIA compares the percentage reduction in cancer risks or noncarcinogenic exposure ratio with the percentage increase in compliance costs. The Incinerator RIA does not compare costs and benefits at all. The costs estimated are the compliance costs to move existing incinerators into compliance with the current regulations. Comparable benefits are not estimated, only health risks when complying with the current regulations and the health risks mandated by a possible alternative regulatory approach.

ES.3 SUGGESTIONS FOR IMPROVEMENT

Based on the framework outlined above and our comparative analysis of the eight RIAs, we have developed a set of specific suggestions of ways in which hazardous waste RIAs might conform more closely to EPA's guidelines in the future. These suggestions are described below under 12 general headings.

ES.3.1 Broader Perspective

The adverse effects of the releases of hazardous substances, in addition to health effects, should be discussed and, where possible, estimated. For example, if contaminated well water is detected, the health effects may be zero, but the costs of alternate water supplies and aquifer cleanup may be large. However, care must be taken to avoid double counting of adverse effects.

Releases to all relevant media should be estimated as well as all relevant routes of exposure from each medium. Thus, care should be taken to omit media or exposure routes from the benefits estimates only if their effects are likely to be insignificant.

ES.3.2 Quantitative Analysis of Several Alternatives

Future RIAs should generate quantitative estimates of benefits and costs for the proposed regulation and at least one regulatory alternative. The regulatory alternatives analyzed should represent significantly different approaches to that of the proposed regulation. These alternatives should be selected from those that have been considered during the regulatory development process. To the extent that only a narrow range of options was considered during regulatory development, the RIA will necessarily have a narrower scope.

ES.3.3 Derivation/Presentation of Input Parameter Values

Data sources should be described clearly and references included where appropriate. Survey data are a good, reliable source of data from industry. In RIAs that rely more heavily on reporting data, discussions of the limitations of that data and the likelihood and extent of under- or overreporting should be included. In RIAs that use estimates provided by a subcontractor, the primary data sources, whether industry sources, engineering estimates, or informed judgment, should be indicated so that the degree of certainty about the estimates may be ascertained.

Input parameter values should be tabulated for each estimation model used. Although uniformity in parameters estimates is not necessarily desirable or possible, all RIAs should include tables that list the values (or distributions) assumed for all input parameters so that the reader can easily compare the parameter values used in different RIAs.

ES.3.4 Methods for Cost Estimates

The effects of the regulation on the products markets should be described in an economic framework. For example, a supply/demand framework might be used.

The estimation method chosen should be selected on the basis of clearly defined decision rules. For example, such decision rules might be derived using a simulation approach to determine when the more simplistic models are likely to misrepresent significantly the true costs of the regulation. The degree of misrepresentation might depend on the magnitude of the compliance costs relative to total industry costs and the elasticities of supply and demand in the products markets.

Cost estimates should include a broader definition of costs than industry compliance costs. For example, the degree to which these costs are passed on to the consumer as higher product prices should be estimated. Also, costs due to unemployment and dislocation of capital should be estimated.

ES.3.5 Products Markets Trends and Exposures

The regulations' compliance costs may change the volume of hazardous waste generated in future years. Such changes may change exposures and should be discussed and estimated if likely to be significant.

Some attempt should be made to incorporate into the analysis overall market trends for the affected industries. Such trends can have a major effect on the projected benefits and costs of a regulation over a multiyear period. For example, if generation of a hazardous waste is likely to decline in the future, the cost and exposure impacts of the regulation will be less than if more hazardous waste is likely to be generated.

ES.3.6 Release, Fate, and Transport Models

Use or develop transport models that allow variability in both level and duration of releases. For example, the Wilson and Miller Groundwater Transport model assumes a steady-state release whereas the PLUME and RANDOM WALK Groundwater Transport models are able to estimate exposure levels and durations that result from variable release levels and durations. The latter models or other similar models should therefore be used in future RIAs.

Make more realistic assumptions for models estimating releases of toxic chemicals from landfills for: degradation of the toxic chemicals in the landfill, concentration of toxic chemicals in leachate, concentration of toxic chemicals in free liquids, total volume of leachate, volume of leachate collected in leachate collection system, content of leachate collected in leachate collection system, and fate of leachate collected in leachate collection system. The existing models have either ignored or made overly simplistic assumptions about some of these factors (for example, no degradation of the chemical in the landfill). Models estimating releases to groundwater should be reviewed carefully by EPA and an approach developed that explicitly deals with all the factors listed above as well as other relevant factors.

ES.3.7 People Affected by the Regulation

Distinguish between people affected by compliance activities and people affected because of changes in releases of the toxic chemical. Among those affected by compliance activities, include a discussion of the relative importance of business owners, employees, and consumers.

Develop a more consistent methodology for estimating the number of people exposed to contaminated groundwater, surface water, and soil. The RIAs analyzed vary greatly in the methods used to estimate the number of people exposed by route of exposure. Because this is a key variable in determining health effects, it might be useful for EPA to develop a methodology for population exposed to soil, surface water, and groundwater to complement the EPA GEMs Modeling System for air. In this way, a more consistent approach to this estimation would be encouraged for future RIAs.

ES.3.8 Realistic Timing

Choose a common period of waste disposal for the estimates of benefits and costs. Because the goal of an RIA is to enable comparison of the benefits and costs of new regulations, it is important that a common basis be used for estimating these benefits and costs. The most logical approach is to choose a period of waste disposal--either 1 year or 20 to 30 years--and compute the benefits and costs attributable to the new regulations for that disposal period. For a given disposal period, duration of release to the different media should also be estimated explicitly for different disposal methods. For example, releases to air from incineration occur only during the disposal period, while releases to groundwater from landfills may occur for up to 200 years after the end of the disposal period. Based on the duration of release to the environment, the duration of exposure from the different routes and disposal methods should also be estimated explicitly.

Discuss and present estimates, if possible, of the timing of the harmful health effects relative to time of exposure. There is an important difference in timing for cancers and noncancers that should, at a minimum, be discussed;

viz for cancers there is generally a long lag time after exposure (20 to 30 years) while noncancer effects may be experienced immediately. The lag time of the health effect determines the average age of the persons likely to experience the harmful health effects.

ES.3.9 Valuation of Health Benefits

Dollar valuation of health benefits should, at a minimum, be discussed in future RIAs. A large literature exists on the topic, and the EPA RIA guidelines describe appropriate methods that can be used to value both morbidity and mortality. Thus, it should also be possible to assign dollar values to the health benefits. An alternative approach is to estimate threshold values for the health benefits, at which values the benefits would just exceed the costs of the regulation.

ES.3.10 Benefit-Cost Comparisons

Comparisons of health effects with other dollar costs or benefits should be made for comparable durations of disposal. Annual costs, for example, should be compared to the change in health effects attributable to a single year of waste disposal. If this is not done, such cost-effectiveness estimates will be misleading for decisionmakers.

So that the decisionmaker will have information available in a useful format, the comparison of benefits and costs should be presented in a table as well as being discussed in the text. Both qualitative and quantitative estimates of the benefits and costs should be presented in this table so that the decisionmaker can make his/her own judgment about whether the unquantified benefits and costs are likely to be of sufficient importance as to change the decision he/she might make on the basis of the quantitative estimates alone. The discussion of the table should provide a summary of the implications of the entire analysis for the decisionmaker.

ES.3.11 Sensitivity/Uncertainty Analysis

Sensitivity analysis should be performed when there is considerable uncertainty about the values of some of the input parameters. For example, the results of the exposure impacts analysis and the dose-response relationships both are estimated with considerable uncertainty. Sensitivity analysis should be performed for the exposure estimates and the dose-response relationships to provide information about the impact of changes in these parameter values. Full-scale uncertainty analysis should be used only to the extent that the results can be presented in a way that improves the decisionmaker's ability to make informed judgments.

ES.3.12 The RIA as a Complete Document

The RIA should include a combination of text and appendixes such that the results are reproducible by the reader from the RIA alone. Since the methods used for performing benefit-cost analyses for hazardous waste regulations are not standardized, it is important for all methods used to be described clearly. Equations should be presented in appendixes where appropriate. The results of each stage of the analysis should be presented in tabular form (e.g., waste characterization, release rates, and exposure concentrations) so that the reader can easily follow the steps of the estimation process. References to supporting documents cannot substitute for such detail within the RIA document, even if the bibliographical reference is complete. The supporting document may not be readily obtainable.

The text should avoid lengthy background discussions and should clearly and concisely present the benefit-cost analysis methodology and results. If more detailed discussion seems necessary (e.g., for the derivation of input parameter values), it should occur in an appendix. For example, only the summary of data derived from the industry profile should be included in the text. The industry profile should be presented in an appendix.

In order to facilitate the implementation of all these suggested improvements, we recommend that EPA prepare a reference handbook that would complement the RIA Guidelines. Such a handbook might include: a brief but detailed description of all relevant, currently used estimation models and a set of decision rules for choosing among them; for each estimation model, tables of commonly used input parameter values and their sources; and a listing of major data sources that might be useful for hazardous waste RIAs. The handbook also should present suggested refinements to currently used methods, where appropriate. The appendixes for the RCRA Risk-Cost Analysis Model and a more recent report Risk Assessment Methodology for Hazardous Waste Management provide a convenient starting point for such a reference work.

With the use of such EPA reference documents, the increase in resources needed to achieve all the improvements suggested above may not be large. Some of them involve only clearer presentation of the results of the analysis, including data sources and parameter values used (3), cost-benefit comparisons (9), and overall organization of the report (12). The other suggested improvements might require the use of additional models, but the burden on the preparer of the RIA can be minimized by developing a centralized listing of all such models and central access to the computer programs for them. Even if resource or data limitations prevent additional modeling, all these other suggested improvements can be addressed qualitatively, clearly presenting the methods used in the analysis and how more extensive modeling is likely to affect the results.

SECTION 1

PURPOSE OF REGULATORY IMPACT ANALYSES

Executive Order 12291, issued by President Reagan on February 17, 1981, requires that Federal agencies prepare a regulatory impact analysis (RIA) for their new major regulations. This order was intended to ensure that regulations would be subject to a rigorous benefit-cost analysis before they could be promulgated and that alternatives to regulation would be considered. As stated in the Environmental Protection Agency (EPA) Guidelines for Performing Regulatory Impact Analyses, "...by developing and organizing information, quantifying and monetizing benefits and costs to the extent possible, and determining distributional effects and economic impacts, the RIA should provide decisionmakers with a comprehensive assessment of the implications of alternative regulatory actions" (EPA 1983).

The Executive Order presumes the existence of generally accepted methods for benefit-cost analysis of environmental regulations. More importantly, it presumes that sufficient data are available to perform such an analysis. Neither of these requirements is met in practice. Often, substantial judgment is required to piece together even a small fraction of the information that would be required for a complete benefit-cost analysis. Thus, RIAs are likely to vary in the degree of quantification of benefits, compliance costs, and economic impacts, and in the precision of such estimates.

The EPA's Guidelines for Performing Regulatory Impact Analyses (1983) represent an attempt to reduce the variability in the RIAs produced by the Agency, at least in terms of the methods and scope of the analysis. The guidance document is used here as the basis for our comparative analysis of eight recent hazardous waste RIAs performed for EPA. The results of this comparative analysis are used to suggest ways to improve the hazardous waste RIAs that will be performed in the future.

SECTION 2

OVERVIEW OF AN RIA

Figure 2-1 illustrates the eight main components of a hazardous waste RIA. The RIA should start with a brief description of the nature of the problem that the proposed regulations are designed to correct as well as the Agency's statutory authority to impose such regulations. The current and proposed regulations and other regulatory alternatives to be analyzed are presented next. Major sources of data used in the analysis are then described, including data on the number and types of releases from hazardous wastes, and alternative disposal methods and their costs. Supplementary data needed for each specific estimation model used in the analysis can be presented later with the estimation models.

The analysis of impacts on products markets uses an economic model to determine how the new regulations will affect the prices and quantities of goods produced in all the affected markets. Impacts on employment level and plant closures are estimated as part of this analysis. The analysis of impacts on products markets provides inputs into two further components of the RIA: estimating the benefits due to the resulting changes in exposure to hazardous substances and estimating the costs of the new regulation due to the compliance activities.

New regulations for managing hazardous wastes may reduce releases of the toxic substances into the environment in two ways: through the use of different disposal technologies or cleanup methods; and through reductions in the generation of the hazardous waste. The exposure analysis estimates the accompanying changes in environmental contamination and human exposure attributable to the new regulations. The results of the exposure analysis can be used to estimate the benefits from regulatory action. Generally, the major benefit expected as a result of hazardous waste regulations is an improvement in health for persons at risk of exposure. Other benefits may occur such as fewer communities having to find alternative water supplies or engage in costly cleanup activities when aquifers become contaminated.

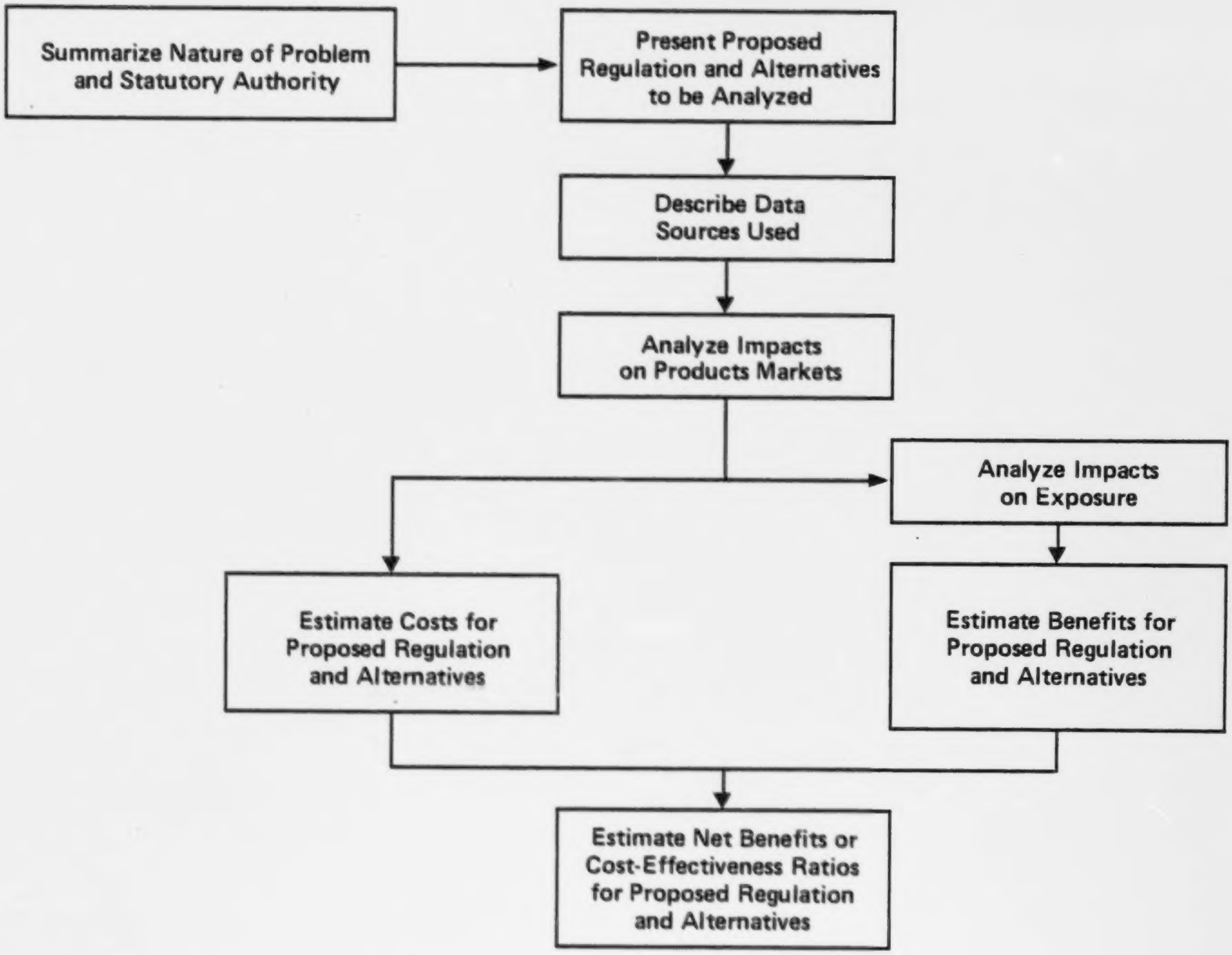
Summarize Nature of Problem and Statutory Authority
Present Proposed Regulation and Alternatives to be Analyzed
Describe Data Sources Used
Analyze Impacts on Products Markets
Analyze Impacts on Exposure
Estimate Costs for Proposed Regulation and Alternatives
Estimate Benefits for Proposed Regulation and Alternatives
Estimate Net Benefits or Cost-Effectiveness Ratios for Proposed Regulation and Alternatives

Figure 2-1. Flow chart for hazardous waste RIAs.

The promulgation of a regulation results in costs that include: increased production costs incurred by industry, increased product costs to consumers, consumer and producer surplus losses, dislocation costs from unemployment of labor and capital, and government costs from regulation. In some cases, a new regulation may result in reduced costs to producers and consumers in at least some market sectors.

The final component of the RIA compares the estimates of costs and benefits. This comparison should provide decisionmakers with a comprehensive assessment of the implications of alternative regulatory actions.

Sections 3 through 10 present the framework for analysis for each of these eight components of an RIA. Following the framework discussion in each section, the approach actually used in eight recent hazardous waste RIAs is analyzed and compared to the suggested framework in a series of tables and accompanying text. The RIAs are referred to by short titles in the tables. Their full titles, as well as the short titles are presented in Table 2-1. Based on this comparative analysis, ways to improve future RIAs are suggested. A framework for analysis for an RIA as a complete document is also presented and applied to the eight RIAs in Section 11. Section 12 concludes the report with a summary of the suggestions for improvements.

TABLE 2-1. REGULATORY IMPACT ANALYSES

Abbreviated title	Full reference
1. Contingency Plan:	Regulatory Impact Analysis of the Revisions to the National Oil and Hazardous Substances Pollution Contingency Plan. ICF, Inc. For U.S. EPA, Office of Emergency and Remedial Response. 1983.
2. Used Oil:	Regulatory Impact Analysis of Proposed Standards for the Management of Used Oil. Temple, Barker, and Sloane. For U.S. EPA, Economic Analysis Branch, Office of Solid Waste. November 1985.
3. Small-Quantity Generators:	Regulatory Analysis for Proposed Regulation Under RCRA for Small Quantity Generators of Hazardous Wastes. Industrial Economics. For U.S. EPA, Office of Solid Waste, June 1985.
4. Reportable Quantities:	Regulatory Impact Analysis of Reportable Quantity Adjustments Under Sections 102 and 103 of the Comprehensive Environmental Response, Compensation, and Liability Act. ICF, Inc. For U.S. EPA, Emergency Response Division, March 1985.
5. Incineration:	Supporting Documentation for the RCRA Incinerator Regulations. PEER Consultants, for U.S. EPA, Office of Solid Waste and Emergency Response, October 1984.
6. Land ban:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Hazardous Wastes. Industrial Economics, Inc. and ICF, Inc. For U.S. EPA, Office of Solid Waste. December 1985.
7. Dioxins:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Certain Dioxin-Containing Wastes. Industrial Economics, Inc. For U.S. EPA, Office of Solid Waste. Draft Final Report. January 1986.
8. Solvents:	Regulatory Analysis of Proposed Restrictions on Land Disposal of Certain Solvent Wastes. Industrial Economics. For U.S. EPA, Office of Solid Waste. Draft Report. January 1986.

SECTION 3

NATURE OF PROBLEM AND STATUTORY AUTHORITY

3.1 FRAMEWORK FOR ANALYSIS

The introduction section for an RIA should be brief, summarizing the specific nature of the environmental problem in terms of releases of toxic substances to the environment and the resulting impacts on people or their environment. The existing market imperfections that prevent a nongovernmental solution should be described. Additionally, the statutory authority under which regulations may be promulgated and time and other constraints influencing the regulation process should be outlined.

3.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 3-1 presents the comparative analysis of the eight RIAs. The nature of the problem, the resulting harm to people, and the governing statutory authority are discussed in every RIA. Impact on the environment, however, is discussed in only two RIAs. The need for government regulation, relative to the existing market, is discussed in only one RIA. Time and other constraints are addressed when relevant.

3.3 SUGGESTIONS FOR IMPROVING RIAS

In addition to human health effects, all RIAs should discuss, in the introduction, the impact on the environment resulting from hazardous releases, identifying the extent and type of environmental damage likely to result. Market imperfections that necessitate a governmental regulation should also be discussed in the introduction to assess the need for a governmental regulation. Such an assessment is required by the OMB.

TABLE 3-1. NATURE OF PROBLEM AND STATUTORY AUTHORITY

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Nature of problem	Releases of oil and hazardous substances to water and protection of environment when discharges do occur	Management of used oil	Disposal of hazardous waste from small-quantity generators	Releases of hazardous wastes to all environmental media from spills/accidents
Harm to people	Cancer and noncancer health effects	Cancer and noncancer health effects	Cancer and noncancer health effects	Cancer and noncancer health effects
Harm to environment	Adverse impacts on property values and community development	Damage to fish, vegetation, wildlife mentioned	Mentioned	Adverse impacts on vegetation, crop, animals
Market imperfections	Discussed reasons for regulatory control	Not discussed	Not discussed	Not discussed
Statutory authority	CERCLA	RCRA	RCRA	CERCLA
Time constraints	Not discussed	Not discussed	Not discussed	Not discussed
Other constraints	Not discussed	Not discussed	Not discussed	Not discussed

(continued)

TABLE 3-1. NATURE OF PROBLEM AND STATUTORY AUTHORITY (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Nature of problem	Stack emissions from hazardous waste incinerators	Land-disposed wastes	Disposal of dioxin-containing wastes, especially land disposal	Disposal of solvent wastes, especially land disposal
Harm to people	Cancer and noncancer health effects	Cancer and noncancer health effects	Cancer and noncancer health effects	Cancer and noncancer health effects
Harm to environment	Not discussed	Not discussed	Not discussed	Contamination of aquifers
Market imperfections	Not discussed	Not discussed	Not discussed	Not discussed
Statutory authority	RCRA	RCRA	RCRA	RCRA
Time constraints	Not discussed	2-yr deadline because of land disposal ban	2-yr deadline because of land disposal ban	2-yr deadline because of land disposal ban
Other constraints	Not discussed	Not discussed	No alternative treatment facilities; delay rule 2 yr	Not discussed

SECTION 4

REGULATORY ALTERNATIVES ANALYZED

4.1 FRAMEWORK FOR ANALYSIS

This section should describe the current regulations, which represent the baseline alternative (no further regulation) against which all new regulations can be compared. The EPA guidelines mention four alternative categories of new regulations that should be compared with this baseline alternative: alternatives to Federal regulation; alternatives within the scope of current legislative provisions including the degree of control imposed, effective compliance dates, and methods of ensuring compliance; market-oriented regulatory alternatives; and major alternatives beyond the current scope of Agency legislative authority. However, resources are limited and it is unlikely that any RIA will or should do a full quantitative analysis of alternatives from all four categories. Some discussion of the full range of possible alternatives and complete analysis of a few is probably sufficient. The choice of those analyzed should be based on those considered during the regulatory development process.

4.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 4-1 presents the comparative analysis of the eight RIAs. All eight RIAs discuss the regulatory alternatives under consideration and the baseline alternative. The latter is often presented in a separate industry profile section. No RIA addresses alternatives to Federal regulation, and most do not discuss market-oriented regulatory alternatives and alternatives beyond current legislative scope.

4.3 SUGGESTIONS FOR IMPROVING RIAs

The primary purpose of this section is to present all of the possible regulatory and nonregulatory alternatives and to identify the ones that will be analyzed in the RIA. Alternatives to Federal regulation, market-oriented

TABLE 4-1. REGULATORY ALTERNATIVES ANALYZED

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Baseline	Ten percent of spills would come under jurisdiction of Federal or State governments	Unregulated	Currently allowed to dispose of waste in Subtitle D landfills and sewer systems	Reporting required for releases of 1 pound of designated hazardous substances except those assigned an amount under Section 311 of the CWA
Alternatives to Federal regulation	Not discussed	Not discussed	Not discussed	Not discussed
Alternatives within legislative scope	Two alternatives that expand current regulation to cover releases of any hazardous substances to any environmental media. Alternate approaches to setting priorities, enforcement, State participation, etc. The two alternatives differ in emphasis on public health and welfare and the environment	Four alternatives: one imposes full hazardous waste standards; three have less stringent standards and different lead content levels	One proposed rule and six possible options that adjust rules for hazardous waste disposal by large-quantity generators to disposal by small-quantity generators	Two alternatives that use different hazard based criteria for determining reportable quantity levels for hazardous wastes (other alternatives discussed, but not analyzed
Market-oriented regulatory alternatives	Tax discussed; not included in analysis	Not discussed	Not discussed	Not discussed
Alternatives beyond current legislative scope	Not discussed	Not discussed	Effects of future regulations discussed	Not discussed
Extent of analysis	Quantitative analysis of direct, indirect, and induced compliance and regulatory costs and exposure reductions from removal and remedial activities for two alternative regulations	Quantitative analysis of costs and health benefits for four alternative regulations	Quantitative analysis of compliance and regulatory costs and health benefits for seven alternative regulations	Quantitative analysis of compliance and regulatory costs for two alternative regulations. Health benefits are only discussed

(continued)

TABLE 4-1. REGULATORY ALTERNATIVES ANALYZED (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Baseline	Destruction and removal efficiency of 99.99% for organics; <1.8 kg/h or 1% of HCl in stack gas; ≤180 mg/dry standard cubic meter particulates	Hazardous wastes currently disposed in Subtitle C landfills or surface impoundments	Dioxins currently disposed in Subtitle C landfills	Solvents currently disposed in Subtitle C landfills, surface impoundments, or land application
Alternatives to Federal regulations	Not discussed	Not discussed	Not discussed	Not discussed
Alternatives within legislative scope	Two alternatives: enforced baseline regulation with some modifications; the other allows for case-by-case performance standards based on a consideration of risk	One proposed regulation: would impose technology-based standards and screening levels for treatment processes; three other alternatives: technology-based standards only, complete land disposal ban, and treatment of contaminated water	One proposed regulation: would impose technology-based standards and screening levels for treatment of dioxin-containing wastes. Five alternative approaches: complete land disposal ban, screening levels only, performance standards based on BDAT, use of BDAT, and no further restrictions	Two proposed regulations: screening levels and technology-based standards; three other alternatives: land disposal ban, partial ban/screening rule, limited land disposal rule
Market-oriented regulatory alternatives	Such approaches as pollution fees; recycle, reuse, disposal incentives; innovation incentives, etc., discussed only	Not discussed	Not discussed	Not discussed
Alternatives beyond current legislative scope	Not discussed	Alternative 3, treatment of contaminated water, currently beyond scope of RCRA amendments	One of the five (no restrictions on land disposal) not allowed under RCRA rule	Not discussed
Extent of analysis	Quantitative analysis of compliance costs for modified and enforced current regulation. Estimates of health risks associated with enforced current and risk-based regulations	Quantitative analysis of compliance costs and health benefits for four alternative regulations	Quantitative analysis of compliance costs and health benefits for proposed regulation only. Impacts of regulatory alternatives discussed	Quantitative analysis of compliance costs and health benefits for two proposed regulations only. Impacts of regulatory alternatives discussed

BDAT = Best demonstrated available technology.

regulatory alternatives, and alternatives beyond current legislative scope should be discussed briefly in this section in addition to the discussion of the proposed and current regulations. Those regulations considered during the regulatory development process should be highlighted. Analysis of all these alternatives may not always be needed or may not be possible. In either case, the reasons should be addressed in this section. However, in general, the quantitative analysis should not be restricted to the baseline and proposed regulations only.

SECTION 5

DATA SOURCES USED

5.1 FRAMEWORK FOR ANALYSIS

One of the most important factors in determining the quality of an RIA is the availability of good data. To the extent that the analysis is based on observed data for the affected industry, the confidence in the results can be high. To the extent that the analysis is based on data derived by informed judgment, a greater degree of uncertainty about the results must prevail. Table 5-1 presents a summary of different types of data sources, their respective advantages and disadvantages, and examples of their use in hazardous waste RIAs.

Because most sources of data include some uncertainty, either because of inherent variability or because of inadequate observation, sensitivity analysis is necessary. It is especially important where the results of the analysis depend upon informed judgment for the values of input parameters. A sensitivity analysis can tell you the degree to which the results are sensitive to changes in assumed parameter values. The more sensitive the results, the more valuable it would be to try to obtain more precise parameter estimates. An alternative type of analysis, uncertainty analysis, may be used where input parameter values are highly variable. In this case, instead of point estimates, probability distributions are estimated for some input parameters and, using Monte Carlo techniques, probability distributions for costs and benefits are generated.

5.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Tables 5-2 and 5-3 present the comparative analysis of the eight RIAs. Every RIA contained some estimates based on informed judgment. Five of the eight performed sensitivity analysis on some or all of the variables in question. Survey data are heavily utilized in half of the RIAs to characterize the wastes, waste facilities, and current management practices. The other

TABLE 5-1. TYPES OF DATA SOURCES

	Example(s)	Advantages	Disadvantages
Reporting data	Hazardous waste spills	Required for all incidents of a particular type	May not be complete, because of incentives for underreporting - if incomplete not a random sample
Survey data	RIA Mail Survey of Treatment, Storage and Disposal Facilities	A random sample, that can be extraplated to the national level	May not be sufficiently detailed, and responses may be inaccurate
Case study data	Impact on environment of spills; trial burns for incineration	Directly observed/measured data	Not necessarily representative
Industry data	Treatment and disposal costs; time burden of regulation	Derived from actual experience	Possible incentives for misrepresentation by industry
Theoretical engineering cost data	Per unit compliance costs for different hazardous waste disposal methods	Theoretically correct for engineering operation	Ignores market factors that might affect actual costs
Estimates from EPA and other publications	Cleanup costs for hazardous waste spills, chemical, climatic, geologic data	Avoids duplication of previous modeling efforts	Quality of estimates only as good as the data sources and models used
Informed judgment	Proportion of spills in three size categories - small, medium, large; incompleteness of reporting data; relationship of past data to present and future; relationship between health effects at high doses in animals to low doses in humans	Based on actual data related to inputs needed for analysis and on previously estimated exogenous variables. Allows quantitative estimation of inputs for which there are very few data or which are not measurable directly.	If underlying data are poor or previously estimated relationships not applicable, informed judgment will not give good estimates. May be biased by individual opinions or goals.

TABLE 5-2. DATA SOURCES USED

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Reporting data	Number and types of releases; relative proportions of generators, transporters, and disposers; geographical distribution of spills		Number of landfills	Number and size distribution of reported releases; response costs; sizes of releases
Survey data			Waste quantities; number of generators (by industry and waste stream); management, storage, and transportation practices; current compliance; geographical distribution of wastes; management costs	Chemical industry hourly labor costs
Case study data				Illustration of public health and welfare and environmental effects
Industry data	Current and projected State response program costs; quantities of offsite and onsite waste disposal	Baseline practices, waste quantities, and costs; distribution of distance from release to water intake	Treatment and disposal costs; transportation costs	Number of notifications; workdays to perform notification processing, monitoring, and removals; current levels of monitoring and direct removals; availability of emergency response resources
Estimates from EPA and other publications	Baseline cleanup practices; cost data; spill incidence projections; waste quantities by SIC code; changes in consumption and spending; firm financial data; regulatory costs to States; value of shipments of chemicals and construction industries	Number and size of model facilities; cost estimates; waste quantities; baseline practices; cost of substitutes; firm financial data; health risks; lead and hazardous constituents concentrations; transportation costs	Transportation costs; availability of transportation services; waste distribution by State; storage costs; compliance costs; regulatory costs; constituent flows; landfill sizes and lifetimes	Number of affected facilities; value of shipments (SIC 28); ignitability, carcinogenicity, aquatic toxicity, and reactivity levels; notification costs; production volumes; cleanup costs; mitigation costs; waste quantities
Informed judgment	Percentage of enforcement costs attributed to revised NCP, expected number of EPA/State enforcement cases (EPA estimate)	Cost of funds; fuel needed for incineration; generator demand elasticities; projection of incineration capacity for used oil; some disposal cost estimates	Modified constituent release profiles from landfills; average exposed population size; lognormal size distribution of releases; waste stream volume equal for each disposal facility	Notification time; percentage of releases cleaned up; national annual reportable releases; degrees of noncompliance

(continued)

TABLE 5-2. DATA SOURCES USED (continued)

Data type	Incineration	Land ban	Dioxins	Solvents
Reporting data	Emissions; number of facilities		Waste quantities; waste generators	
Survey data	Emissions; air dispersion estimates	Waste quantities; current management practices; number of firms	Waste quantities; cost data	Current management practices; waste characterization and quantities; affected facilities; facility sizes
Case study descriptions	Emissions; cost data; waste quantities			
Industry data	Numbers and types of incinerators; current operating practices; waste types and quantities; incineration costs; trial burn costs emissions		Incineration costs; transportation costs; land disposal costs	
Engineering cost data	Incinerator costs; upgrading costs; current operating and capital costs of disposal			
Estimates from EPA and other publications	Dispersion ratios; population exposure; consequences of exposure; health effects; cost data; number of waste facilities; waste composition	Cost data; transportation costs; firm financial data; disposal methods; waste characterization; environmental parameters (dispersion); population data; linear unit risks	Waste characterization; waste quantities and sources; production levels; dioxin concentrations; incineration costs; tansportation costs; firm financial data; average releases; health risks; geographical distribution of wastes	Waste stream characterizations; constituent toxicities; cost data; transportation costs; firm financial data; constituent concentration levels; hydrologic variables; emissions; number of waste generators; linear unit risks
Informed judgment	Percentage of waste that is carcinogenic	Percent of spill volume cleaned up	Baseline assumptions--levels of residuals from incineration, land disposal; No co-disposal w/ mobilizing constituents and no wind dispersal	Wastes meeting treatment standards or prohibited from land disposal; double liners used; waste pile storage=1 yr; transportation distances; distillation of organic liquids containing solvents; offsite unit prices

TABLE 5-3. SENSITIVITY ANALYSIS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Use of sensitivity analysis	Yes	No; although does contain discussion of implications of assumptions	Yes	Yes
Variables	Percentage of cost of enforcement attributable to the NCP; unit costs of remedial and planned removal actions; the extent of voluntary private sector cleanup induced by regulation		Generation rate constant for all wastes	Percentage of reportable releases that go unreported; notification time; frequency of on-scene monitoring; frequency of off-scene monitoring
Source of data for variables subject to sensitivity analysis	Informed judgment		Informed judgment	Informed judgment; reporting data; survey data; publications

(continued)

TABLE 5-3. SENSITIVITY ANALYSIS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Use of sensitivity analysis	Yes	No	No	Yes
Variables	Stack height			Transportation distances; distillation costs
Source of data for variables subject to sensivity analysis	Informed judgment			Informed judgment

half primarily use reporting data and previous EPA reports for their waste characterizations. Estimates from publications usually refer to data provided in a report from a subcontractor or from a previous EPA report. Industry sources are used in many of the RIAs for data on current practices, costs, and resources available for cleanup programs. Cost data in the Incinerator RIA are provided by a very detailed engineering cost-estimation process.

5.3 SUGGESTIONS FOR IMPROVING RIAs

Estimates based on informed judgments should always be treated with caution. Formal sensitivity analysis should be performed for the more important input parameters, while a discussion of the implications of assumptions should suffice for the less important variables. Survey data are a good, reliable source of data from industry. In RIAs that rely more heavily on reporting data, discussions of the limitations of that data and the likelihood and extent of under- or overreporting should always be included. In cases that utilize estimates provided by a subcontractor, the primary data sources, whether industry sources, engineering estimation, or informed judgment, should be indicated so that the degree of certainty about the estimates may be ascertained. Industry sources provide a fairly reliable source of information, but in some cases, may be influenced by industry opinions or goals. Such motivations should be mentioned when relevant. In the one RIA that estimated costs by engineering method, the results should be theoretically correct. However, the method appeared to be quite resource-intensive and did not reflect the market forces that might affect actual costs. Such ramifications should be examined if this cost estimation approach is used.

SECTION 6

PRODUCT MARKETS IMPACTS ANALYSIS

6.1 FRAMEWORK FOR ANALYSIS

The objectives of the products markets impact analysis can be listed as follows:

- To project long-run changes in equilibrium prices and output rates in directly regulated markets
- To project the impact on prices and outputs in markets that sell to or purchase from the directly regulated markets
- To project the impact on prices and outputs in markets for complements and substitutes
- To determine how short-run impacts will differ from long-run impacts
- To determine which regulated facilities will be most affected
- To project the employment impacts
- To project dollar estimates of the changes in consumer and producer welfare
- To determine who will bear larger shares of the costs of the rule: the consumer or the producer.

Consideration of all these modeling objectives should be explicit in the RIA. If the scope of the analysis is limited to a subset of these objectives, the rationale should be clearly explained.

6.1.1 Select Markets to be Modeled and Develop Industry Profiles

Before the products markets impact analysis can be performed, the products likely to be affected by the new regulations must be identified and an industry profile developed for the industries producing these products. The products markets affected by the new regulations include those to be regulated directly as well as those supplying the inputs to and using the outputs from these regulated markets. Markets for complements and substitutes for the regulated products may also be affected. Identifying even the directly regulated products markets can be difficult, given the heterogeneity of products and production processes that may be subject to a regulation. Selecting many markets to analyze will require large amounts of data and may entail the construction of complex estimation models, capable of accounting for interactions between the markets. However, restricting the analysis to directly affected market(s) only may result in unrealistic estimates of the impacts of the regulation. The RIA should discuss this tradeoff and explain the basis for the markets chosen for analysis.

The industry profiles should include an examination of: market conditions, for example, prevailing supply and demand constraints and expected growth trends; market structure, for example, number of firms in each market and four-firm concentration ratios; market conduct, for example, competitive or monopolistic; and market performance, for example, annual return on investment. Such industry profiles establish the baseline from which the impacts of the new regulations must be determined.

6.1.2 Develop Estimation Model

The complexity of the estimation model developed will depend on the chosen scope of the analysis, especially in terms of the number of markets modeled, their relationships, and the time periods of interest. If price and output impacts are to be projected in several related markets, a partial equilibrium model is needed. Projections of the time paths of price and output changes would require a dynamic model.

A diagrammatic exposition of the modeled markets should be included so that assumptions about the shapes and interrelationships of the supply and demand curves in the different markets are clearly demonstrated to the reader. For example, a typical competitive market might include a horizontal long run supply function and a downward sloping demand function. In this case, increased production costs, shown by a shift upward of the supply curve, will be borne by consumers. A higher product price will cause consumers to purchase less, and the level of production will decline to restore equilibrium. Employment and capital dislocation may accompany production declines, imposing costs on workers and shareholders. Finally, consumers will incur a deadweight surplus loss on the foregone consumption. The mathematical formulation of the estimation model should also be documented.

6.1.3 Estimate Disposal/Cleanup Costs and Other Model Input Parameter Values

Development of the estimation model is followed by collection or estimation of required input data. Projection of economic impacts requires, at a minimum, estimated costs of compliance with the rule. Compliance costs are determined by the technical alternatives available to those affected by the rule and the associated costs of implementation. Two main approaches are available to estimate these costs: statistical cost estimation and engineering cost estimation.

Statistical cost estimation assumes the existence of actual plant data on costs and processes both with and without the new regulation. Such data can be used to obtain estimates of the share of total cost attributable to the new processes required by the regulation. Unfortunately, such data are rarely available.

The engineering cost approach is a viable alternative that does not rely on the availability of actual plant data. Engineers, who are familiar with the relevant technical processes, establish theoretical relationships among technical inputs, outputs, residuals, and costs. These relationships are then applied to representative model facilities to estimate industry costs of compliance.

Other important input parameters in economic impacts models are demand and supply relationships. Demand and supply elasticities may be estimated using primary data taken from previous studies, or derived using informed judgment based on available data. Given adequate resources, estimation is ideal. However, data needs can be substantial, making estimation practicable only for the most ambitious analysis. Previous studies do define demand characteristics for a number of industries, but for most industries they are unavailable. Supply characteristics are available less frequently. When using informed judgment to estimate demand and supply relationships, assumptions should be made explicit, not implicit. Further, the validity of the assumed values should be addressed, as well as the sensitivity of the results to changes in the values of such input parameters.

Depending on the design of the estimation model, other input parameter values may be required. Cross-price elasticities defining relationships between goods that are complements or substitutes will seldom be available from published sources and would need to be estimated or assumed. Secondary data may yield estimates of such parameters as market shares, cost shares, output distribution shares, and employment coefficients. The RIA should clearly state the sources of all such data employed in the model and the justification for, validity of, and implications of their use.

6.1.4 Identify Facility/Industry Compliance Methods Chosen

Hazardous waste regulations sometimes involve requirements that particular processes and practices be employed. In this case, compliance may require the purchase and installation of specific capital equipment. However, firms may be allowed to choose among alternative acceptable disposal methods. In this case, it is generally assumed that firms will comply in the least-cost way. The assumption of how firms (and the industry) will comply should consider the time frame in which we assume they are making their decision. This assumption should be explicit in the RIA.

6.1.5 Project Equilibria Impacts

Market impacts follow changes in industry marginal costs (supply) exogenously prompted by the rule. A discounted cash-flow model using an appropriate discount rate is generally developed to estimate supply shifts given the estimated costs of compliance. All projected price and output rate impacts should be clearly presented and discussed. If the estimation model projects impacts in percentage terms, these results should be converted to absolute values using appropriate baseline data.

Depending on the complexity of the model, the magnitude of the projected impacts, the reliability of the input data, and other factors, a formal or informal sensitivity analysis may be desired. The RIA should present the justification for doing or not doing such an analysis. If a sensitivity analysis is conducted, the RIA should present the methodology, the results, and the implications of these results.

6.1.6 Project Effects on Plants, Employment, Profitablity

The RIA should include a discussion of potential impacts on facilities. Reductions in output may be accompanied by some combination of facility closures, facility output reductions, hastened closure of facilities that were going to close in the near future, or delay in the opening of new facilities.

Accurate projection of facility closures requires knowledge of actual facility cost structures. Such data are typically not available. If the RIA does project closures, it should explicitly state the basis for the projection.

Employment impacts are correlated with facility impacts, though only imperfectly. Consequently, their accurate projection requires similar data and is subject to the same limitations. Employment impact projections should be explained explicitly. If employment projections are made using a fixed employment-to-output ratio, the limitations of the projections should be explicit.

Impacts on "profitability" are really in the realm of cost projections, which are the topic of Section 9. Projections of impacts on trade, capital availability, and other variables are relatively uncommon because of the speculative nature of such exercises. Any such projection should be accompanied by an explicit discussion of the economic foundations of the framework used to develop them, and their limitations should be discussed.

6.1.7 Analyze Small Business Impacts

Analysis of small business impacts, as frequently required under the Regulatory Flexibility Act, usually begins with an explicit definition of "small business" and a rationale for using that definition.

The RIA should state how many small businesses are believed to be in affected industries and the source of that data. If it is assumed that small businesses and small facilities are one and the same, this should be indicated.

Most small businesses are privately held, so certified financial data are unavailable. However, it is known that financial structures of small businesses frequently differ from those of large businesses. Small businesses are typically more leveraged with short- and long-term debt and may finance any required capital differently. Financial impact projections should take this into account, but underlying assumptions should be stated clearly.

Projections of other types of small business impacts, such as closures, are at least as difficult to make as those for large firms, which have been discussed previously. Problems are compounded by the paucity of data for small businesses.

When adequate data are available, the significance of impacts should be analyzed along the lines suggested by Agency and other guidelines for compliance with the Regulatory Flexibility Act.

6.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Only in the Used Oil RIA were the objectives for the products markets impact analysis comprehensively discussed. In the remaining RIAs, market impacts, as opposed to compliance costs, were mentioned only briefly or not at all.

6.2.1 Selection of Markets to be Modeled and Industry Profiles

All eight RIAs identify and discuss in some detail the markets that would be directly affected by the regulations. The framework suggests tnat relationships between different regulated markets and between these markets and important unregulated markets should be considered. The presence or absence of important relationships should help determine which markets are explicity modeled and which are not. The markets modeled are presented in Table 6-1 for the eight RIAs. Only the Used Oil RIA presents a comprehensive market model. In this RIA, the regulated markets are modeled, other markets are not. Potential impacts in other markets are, however, discussed.

The degree to which the RIAs present a formal industry profile is also presented in Table 6-1. Only three of the eight RIAs discuss supply and/or demand conditions in the regulated industries. Five of the RIAs discuss industry structure. Market conduct is an important component of industry profiles. It is usually in this section that conclusions are drawn about pricing behavior of market participants. These conclusions largely determine the appropriateness of constructing competitive, monopolistic, or other models to project regulatory impacts. Only two of the RIAs contain these important discussions. The performance section typically contains an assessment of an industry's financial health and/or baseline projections of industry growth in the absence of regulation. Two of the RIAs assess the financial performance of regulated industries.

6.2.2 Estimation Models Used

Table 6-1 includes a summary of the analytical framework and estimation models used in the eight RIAs. The Used Oil RIA models the regulated markets

TABLE 6-1. MARKETS MODELED AND ANALYTICAL FRAMEWORK

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
REGULATED MARKETS IDENTIFIED				
	Waste generators, transporters, disposers identified; cost incidence by SIC code projected	Three markets identified and discussed (generators, intermediate users, and end users), data from published reports, reports for EPA, and industry sources	Small-quantity generator market identified and discussed; data from small-quantity generator survey	Affected industries identified
MARKETS MODELED				
Regulated	No formal modeling	All three markets modeled	No formal modeling	No formal modeling
Other	No formal modeling	Other markets and their impacts (e.g., virgin oil) discussed, not modeled	No formal modeling	No formal modeling
INDUSTRY PROFILE				
Conditions	Not discussed	Supply and demand conditions discussed	Discussed price and commercial capacity for the market (supply constraints)	Not discussed
Structure	Not discussed	Discussed industry structures in the three markets	Discussed industry structure	Number of firms included from EPA and census of manufactures data
Conduct	Not discussed	Concludes markets are monopolistic, with subsectors that are price-competitive and monopsonistic	Not discussed	Not discussed
Performance	Not discussed	Includes baseline performance and discussion of financial health	Financial performance discussed	Not discussed

(continued)

TABLE 6-1. MARKETS MODELED AND ANALYTICAL FRAMEWORK (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
REGULATED MARKETS IDENTIFIED				
	Identified and discussed incinerator manufacturing industry and incinerator facilities	Identified and discussed data from RIA mail survey	Identified and discussed data from surveys and reported information	Waste generators identified, and waste disposal industries identified and discussed; data from RIA Mail Survey, small-quantity generator survey, EPA reports, and TSDF questionnaire
MARKETS MODELED				
Regulated	No formal modeling	No formal modeling	No formal modeling	No formal modeling
Other	No formal modeling	No formal modeling	No formal modeling	No formal modeling
INDUSTRY PROFILE				
Conditions	Not discussed	Mentions present industry conditions	Not discussed	Not discussed
Structure	Number of facilities estimated from pollution equipment buyer's guide and EPA data bases	Industries and number of firms identified from RIA Mail Survey	Not discussed	Not discussed
Conduct	Not discussed	Discusses competitiveness of several industries	Not discussed	Not discussed
Performance	Not discussed	Discussed	Not discussed	Not discussed

(continued)

TABLE 6 1. MARKETS MODELED AND ANALYTICAL FRAMEWORK (continued)

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
ANALYTICAL FRAMEWORK				
Explicit supply/demand framework	No	Yes	No	No
General or partial equilibrium	NA	Partial	NA	NA
Static or dynamic	NA	Static	NA	NA
Presentation of mathematical model	Cost calculations included	Yes, presented in background document	None	None
Presentation of operational model	None	None	None	None

NA = Not applicable.

(continued)

TABLE 6-1. MARKETS MODELED AND ANALYTICAL FRAMEWORK (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
ANALYTICAL FRAMEWORK				
Explicit supply/demand framework	No	No	No	No
General or partial equilibrium	NA	NA	NA	NA
Static or dynamic	NA	NA	NA	NA
Presentation of mathematical model	None	Includes cost ratios	None	Mathematical model consists of cost ratios; equations included
Presentation of operational model	None	None	None	None

NA = Not applicable.

in an explicit supply and demand framework. A comparative statics, partial-equilibrium market model is used. A diagrammatic exposition and the mathematical model are clearly presented in a background document, although the operational model (e.g., computer code) is not presented.

None of the other RIAs explicitly models any markets in a supply and demand framework. Two of the RIAs do present formulae used to compute costs of compliance.

6.2.3 Establishment of Disposal/Cleanup Costs and Other Parameter Estimates

This comparative analysis is presented in Table 6-2. The framework indicates that compliance costs can be estimated using either statistical or cost-engineering techniques, the latter being more prevalent. All eight of the RIAs use a cost-engineering method to estimate compliance costs.

Other important modeling parameters mentioned in the framework are demand and supply relationships. Of the eight RIAs, two discuss but do not estimate demand elasticity. The Used Oil RIA does incorporate downward-sloping demand in the impacts model. It also estimates the slopes of important supply functions using cost data. None of the other RIAs explicitly incorporates supply in their estimation models.

6.2.4 Identification of Facility/Industry Compliance Methods Chosen

This comparative analysis is also presented in Table 6-2. Three of the RIAs explicitly state that the regulated firms are assumed to comply with the regulation using the least-cost method for doing so. All others merely indicate that there will be 100 percent compliance based on best demonstrated available technology.

The framework suggests that RIAs address the fact that some firms might choose to close rather than comply with proposed regulations. Only one of the RIAs fails to do so. All others, in fact, propose potential "closure rules." Some are rather sophisticated; e.g., closure is predicted when the net-present value of the complying facility is less than zero, assuming a 3-percent discount rate.

6.2.5 Projection of Equilibria Impacts

Table 6-3 presents the comparative analysis of price, output, and other

TABLE 6-2. INPUT PARAMETER ESTIMATES AND DISPOSAL METHODS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
COST AND OTHER INPUT PARAMETER ESTIMATES				
Baseline compliance methods	Cleanup methods presented; data from EPA reporting information and publication Environmental Emergency Response	Costs estimated by engineering approach; data from published reports and other research reports	Methods discussed, waste management costs estimated from survey by Booz-Allen; transportation costs developed by Pope-Reid Associates	Costs not estimated
Compliance cost estimation	Costs derived from EPA cost estimates	Regulatory costs estimated by engineering approach data from PEDCo and ICF	Estimated by engineering approach as the difference between the costs of baseline and postregulation practices; data from Booz-Allen survey and engineering contractor	Engineering approach to determine costs of compliance; data from TSCA chemical inventory, PIRS data base, reports and articles
Demand functions	Not modeled	Estimated elasticities for intermediate users as function of ATC and market price of used oil products; elasticities for different generators assumed to be 1, 0.75, and 0.25	Not modeled	Not modeled
Supply functions	Not modeled	Upward sloping supply curve estimated from cost data	Not modeled	Not modeled
Other parameter estimates	None	Assumed: cost of debt = 13%, cost of equity = 15%, inflation rate = 6%; elasticity of substitution of 5 obtained from research publication	Assumed: 3% discount rate, 10-yr time horizon (for cash flows)	None
SELECTION OF DISPOSAL/CLEANUP METHDS				
Compliance method adoption	Assumes full compliance	Assumes full compliance	Assumes compliance based on lowest cost method	Assumes full compliance
Compliance/ closure decision	Predicts closure when compliance costs > firm's equity value	Employs dcf model with 6% (inflation) discount rate and assumes compliance if NPV > salvage value	Predicts closure when dcf < 0 at 3% discount rate	Determines no closures will result because costs to firms are very low

dcf = Discounted cash flows.
NPV = Net-present value.
ATC = Average total cost.

(continued)

TABLE 6-2. INPUT PARAMETER ESTIMATES AND DISPOSAL METHODS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
COST AND OTHER INPUT PARAMETER ESTIMATES				
Baseline compliance methods	Full discussion and estimation of baseline practices and costs by engineering approach; data from industry officials	Costs estimated by engineering approach by Pope-Reid Associates	Discussion and estimation of baseline practices and costs by engineering approach; data from reported information	Costs estimated by engineering approach; data provided by engineering contractor (primary sources not included)
Compliance cost estimation	Compliance cost estimated by engineering approach; data from site visit reports and engineering judgments	Estimated by engineering approach as difference from the baseline costs; costs derived by engineering contractor; data sources not included	Cost estimated as difference from baseline to new costs; data from survey results	Estimated by engineering approach as difference from baseline costs; data from engineering contractor (primary sources not included)
Demand functions	Not modeled	Discusses likelihood of passing costs on in higher prices	Not modeled	Discusses price elasticity, but not modeled
Supply functions	Not modeled	Not modeled	Not modeled	Not modeled
Other parameter estimates	None	None	Cash from operations and cost of production estimated from census data	Cash from operations and cost of production ratios; data from 1982 Census
SELECTION OF DISPOSAL/CLEANUP METHODS				
Compliance method adoption	Assume compliance with BDAT for each facility	Assumes full compliance, based on least-cost BDAT	Assume compliance with BDAT	Compliance choice based on minimum cost BDAT
Compliance/ closure decision	Closure not discussed	Predicts closure when compliance costs > 5% of cost of production	Assumes "significant" impacts if compliance cost/ cost of production or cash from operations > 5%; does not estimate number of closures	Significant impacts assumed to result when the cash from operations and cost of production ratios > 5%; closures not estimated

dcf = Discounted cash flows.
NPV = Net-present value.
BDAT = Best demonstrated available technology.

TABLE 6-3. IMPACTS PROJECTIONS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
EXOGENOUS SHIFT OF SUPPLY	Not modeled	Employs changes in production and price to compute change in ATC	Not modeled	Not modeled
PRIMARY ECONOMIC IMPACTS				
Price impacts	Discusses possible price increases on the chemicals industry	Projected in percentage and absolute term for all markets	Not projected; expected to be insignificant at industry level	Not projected; expected negligible impacts
Production impacts	Discusses possible production level changes in chemicals industry	Projected in percentage and absolute terms for all markets	Not projected; expected to be insignificant at industry level	Not projected; expected negligible impacts
SECONDARY ECONOMIC IMPACTS				
Capital utilization/growth	Discusses possible changes in cost of capital and capital availability in chemical industry	Not discussed	Not discussed	Not projected; expected negligible impacts
Employment impacts	Mentions possible employment impacts on chemicals industry	Not discussed	Not projected; expected to be insignificant at industry level	Not projected; expected negligible impacts

(continued)

TABLE 6-3. IMPACTS PROJECTIONS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
EXOGENOUS SHIFT OF SUPPLY	Not modeled	Not modeled	Not modeled	Not modeled
PRIMARY ECONOMIC IMPACTS				
Price impacts	Not discussed	Discussed, not projected	Discussed, not projected	Discussed likelihood of passing costs on in higher prices
Production impacts	Not discussed	Discusses improved waste management	Not discussed	Not discussed
SECONDARY ECONOMIC IMPACTS				
Capital utilization/growth	Not discussed	Not discussed	Not discussed	Not discussed
Employment impacts	Not discussed	Not discussed	Not discussed	Not discussed

impacts. The Used Oil RIA exogenously shifts supply functions in the regulated industries by using a discounted-cash-flow model to compute changes in average total cost. Such a shift is not modeled in the remaining RIAs. Impacts on market prices and output rates constitute "primary" economic impacts of regulations. Seven of the eight RIAs do not project price impacts at all. Of those seven, two explicitly state that price impacts are expected to be insignificant and are thus not projected. Others among those seven discuss price impacts qualitatively, but do not propose "insignificance" as a rationale for not projecting them. The Used Oil RIA projects price impacts both in percentage and absolute terms.

6.2.6 Projection of Effects on Plants, Employment, Profitability

Secondary impacts that might be projected according to the framework include impacts on employment and capacity utilization/industry growth. None of the eight RIAs quantitatively project employment impacts, though some do discuss possible impacts. Seven of the RIAs do not discuss potential impacts on existing or new capital at all. The eighth RIA does discuss possible changes in the cost of capital following regulation.

6.2.7 Regulatory Flexibility and Paperwork Burden Analyses

Table 6-4 presents the comparative analysis of the optional analyses in the eight RIAs. Two of the RIAs contain no analysis of impacts on small businesses at all. Most of the others follow Small Business Administration guidelines to define small business. Four of these go on to assume that small facilities are owned by small firms, the other two have other operating rules. One concludes that impacts would be minimal and has no impacts analysis. The others discuss financial considerations peculiar to small firms, and three discuss potential closures from this perspective.

Two of the RIAs perform some sort of paperwork burden analysis.

6.3 SUGGESTIONS FOR IMPROVING RIAs

There are several practices that should be standard in all hazardous waste regulations products market impact analyses, regardless of whether they are for Regulatory Impact Analyses of major rules or for analyses of less costly rules. These practices should always be included because: (1) they

TABLE 6-4. OPTIONAL ANALYSES

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
PAPERWORK BURDEN ANALYSIS	None	Estimates paperwork burden by number of shipments	None	Determined in terms of hours taken for reporting and recordkeeping
SMALL BUSINESS ANALYSIS				
Definition of small business	Small firms = annual sales ≤ $35 million	SBA guidelines--selected small firms on basis of annual revenues	Entire study conducted for small-quantity generators; median sales = $2,502,400	SBA guidelines--sales under $35 million, fewer than 575 employees
Number of small businesses	Assumes small plants are owned by small businesses	Assumes small plants are owned by small businesses	Assumes small plants are owned by small businesses	Not estimated
Impact analysis	Estimates of closures and cost impacts based on cash flow, equity, and cleanup costs for model firms	Examines profitability/likelihood of closure for small firms	Significant impacts based on compliance cost > 1% of sales and compliance cost > 25% of profits	From sample check, analysis deemed unnecessary

SBA = Small Business Administration.

(continued)

TABLE 6-4 OPTIONAL ANALYSES (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
PAPERWORK BURDEN ANALYSIS	None	None	None	None
SMALL BUSINESS ANALYSIS				
Definition of small business	NA	SBA guidelines; used census financial data for firm size	NA	SBA guidelines--selected small firms on basis of number of employees
Number of small businesses	NA	Assumes small plants are owned by small businesses	NA	Assumes small plants are owned by small businesses
Impact analysis	NA	Ratio analysis of costs of compliance to costs of production for cash from operations	NA	Ratio analysis examined compliance costs relative to costs of production for cash from operation and likelihood of plant closure

SBA = Small Business Administration.
NA = Not applicable.

are not costly to implement; and (2) they help to make the analytical process explicit. The suggested bare minimum requirements are:

- The analytical objectives chosen should be discussed, along with an explicit statement of the rationale for such choices.
- Regulated markets should be clearly identified, and relationships among the several regulated markets should be discussed as should relationships between regulated and nonregulated markets.
- Markets should be modeled in a supply and demand framework, even if extreme, simplifying assumptions are made; e.g., perfectly elastic supply (horizontal supply functions) and perfectly inelastic demand (vertical demand functions).
- All data for the impacts model should be clearly presented along with their source; it is acceptable to use informed judgment to determine data values, but this should be explicit.
- When implementing an impacts model, it should be made clear what is being assumed about the decisions of firms to comply or to close (or not open).
- When impacts on prices, output rates, employment, and other variables are projected, the mathematical model, operational model, data inputs, and projection results should be presented clearly.
- Whether or not regulatory flexibility or paperwork burden analyses are conducted, the need (or lack of need) and objectives of such analyses should be discussed.

Economic modeling in a rigorous supply and demand framework is indicated in certain circumstances. Most important perhaps is when costs of compliance with a hazardous waste rule would be large relative to baseline revenues and costs of regulated firms. Note that rigorous impacts modeling may be unnecessary even when compliance costs are very high, if they are low relative to baseline costs and revenues, because impacts on prices and quantities may still be trivial. Other factors to consider in this decision are the number of firms regulated, the number of industries regulated, and the timing of the regulation. Regulations affecting only new facilities may merit less rigorous analysis than regulations also affecting existing facilities, because displacement costs to workers and owners of capital tend to be lower for the former.

When formal impacts modeling is attempted, the analyst should be careful to implement several practices:

- Explain and justify the use of a competitive, monopoly, or other type of market model.

- Indicate the type of model used; e.g., dynamic vs. static, partial vs. general equilibrium; and explain the decision to use it.

- Present theoretical and operational models in background documents.

- Clearly tabulate all model input parameters values and how they were obtained.

- Clearly tabulate all projection results in percentage and absolute terms.

SECTION 7

ANALYZE REGULATION IMPACTS ON EXPOSURE

7.1 FRAMEWORK FOR ANALYSIS

The exposure analysis should include estimates of exposures from all possible routes of environmental contamination, both with and without the new regulations. Disposal of hazardous waste can result in contamination of air, surface water, groundwater, and soil. Both humans and other animals may be exposed to this contamination by breathing air; drinking, swimming in, and washing with surface water; drinking and washing with groundwater; and breathing or skin contact with soil particles. Eating fish from contaminated surface water or food grown in contaminated soil may be other routes of exposure.

7.1.1 Waste Characterization

The first step in performing an exposure analysis is to characterize the waste streams or spills that contain the toxic chemicals. Available data must be used to determine the number of waste streams, their geographical distribution, the volume of the waste streams, the concentration of toxic chemicals, and the methods of waste disposal and cleanup with and without the new regulations. If sufficient data are not available to describe the waste stream population directly, a model waste stream approach may be used. In this case, all available data are used to construct "typical" waste streams.

7.1.2 Release, Fate, and Transport Models

The level of human and animal exposure will depend on the release rates of the hazardous substances as well as on their fate and transport in all the exposure media. Observed release rates are unlikely to be available for all waste streams, thus models have been developed for estimating release rates to the four media--air, surface water, groundwater, and soil. Release rates for a given chemical vary according to the volume of the waste or spill, the concentration of the toxic chemical in the waste, the type of disposal or remediation used, and climatic and geologic factors. If the estimated benefits attributable to reductions in releases of toxic chemicals to the environment are to be comparable with the estimated costs attributable to compliance activities, it is important to specify clearly the duration of disposal being modeled in the exposure analysis. Both the duration of the release, as well as its level, for a specified duration of disposal should be estimated. This is especially important when comparing different disposal methods because, for the same time period of disposal, they may result in both different levels and different durations of releases of toxic chemicals to the environment.

Fate and transport models are used to estimate the level and duration of human and other animal exposure to the toxic chemicals released as a result of waste disposal or spills of toxic chemicals. Fate refers to the tendency of a chemical to break down after its release. This breakdown may be due to biodegradation, photolysis, or other chemical reactivity. There is a wide degree of variability in half-life among chemicals, and the RIA should clearly state the assumptions made on the chemical half-lives in different media.

Both analytic and numeric transport models have been developed for use in determining the level and duration of human exposure for a given level and duration of release to a given medium. The results from the transport models depend on release rates and on chemical, climate, and geologic factors. The transport models estimate the concentration of the toxic chemicals at different distances from the point of release and in different media.

7.1.3 Population Exposed

To complete the exposure analysis, it is necessary to estimate the number of people at varying distances from the point of release and thus at risk of varying levels of exposure. The best way to do this is to locate precisely the site of release and then use the most recent census data to determine the number of people at given distances from the site. However, this does not necessarily give you precise information about the size of the population at risk of exposure because, for example, population exposure to air depends on wind direction, and exposure via groundwater depends on the extent to which groundwater is used as a source of drinking water in the region and the size of the aquifer and its direction of flow. Shifts in the size and location of the population may also occur over time.

7.1.4 The Outputs of the Exposure Analysis

The outputs of a complete exposure analysis for the waste streams of interest to the regulator should include, both for the current regulations and all regulatory alternatives being analyzed:

- Realistic estimates of release duration to each medium according to the cleanup or disposal methods used for each toxic chemical
- Estimates of the level and duration of human exposure to these releases at different distances from the site of release
- Estimates of the number of people exposed at each distance from the site of release
- Sensitivity/uncertainty analysis for all the above estimates.

7.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 7-1 presents an overview of the scope of the exposure impacts analysis for the eight RIAs. The two CERCLA RIAs do not estimate actual release rates from the toxic chemical spills because the variability in size and chemical content was considered too great and the data too sparse to allow for adequate waste characterization. The RCRA RIAs all generate quantitative estimates of release rates from model waste streams to some or all of the media--air, groundwater, and surface water--for different waste disposal methods. Although the two CERCLA RIAs discuss releases to soil, none of the RCRA RIAs estimate exposures via soil contamination.

The number of persons exposed for each regulatory alternative is estimated in one CERCLA RIA (Contingency plan) while all but one of the RCRA RIAs include estimates of the number of persons exposed as well as their level of exposure. Only two of the RCRA RIAs also generate estimates of the duration of this exposure for a given duration of waste disposal. Plant and animal exposure is discussed in only three of the RIAs and other environmental impacts discussed in four. No quantitative estimates of the nonhuman health impacts or nonhealth environmental impacts are made in any of the RIAs.

TABLE 7-1. OVERVIEW OF EXPOSURE IMPACTS ANALYSIS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
RELEASES TO:				
Air	Probability of release from improper waste disposal on land	Level and duration from burning, oiling roads, land disposal, storage, and dumping	Level and duration from volatilization from publicly owned treatment works (POTW)	Discussion of releases observed in case studies of spills
Surface water	Qualitative discussion only	Level and duration from oiling roads, scrubber water, storage, dumping	Qualitative discussion only	Discussion of releases observed in case studies of spills
Groundwater	Probability of release from improper disposal on land	Level and duration from storage, dumping, land disposal, ash, still bottoms	Level and duration from landfills	Not discussed
Soil	Probability of release from improper disposal on land	Not discussed	Not discussed	Discussion of release observed in case study of spill
HUMAN EXPOSURE	Number of persons only via air, groundwater, soil	Number of persons and level via air, surface water, and groundwater	Number of persons, level, and duration via air and groundwater	Discussed only
PLANT AND OTHER ANIMAL EXPOSURE	Not discussed	Discussed only	Not discussed	Discussed only
OTHER ENVIRONMENTAL IMPACTS	Discussed only--recreation, property value declines, and community development	Discussed only--costs of cleanup and alternative water supply, loss of potable water, visibility and smell impacts	Discussed briefly	Discussed only--recreation damage, property value, aesthetics, productivity

(continued)

TABLE 7-1. OVERVIEW OF EXPOSURE IMPACT ANALYSIS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
RELEASES TO:				
Air	Level and duration from stack emissions from incinerators	Level from volatilization from landfills, surface impoundments, land treatment, oxidation/reduction, incinerators, fixation/stabilization, distillation, carbon adsorption	Level from incinerator stack emissions and spills from landfills	Level and duration from volatilization from landfills and surface impoundments and stack emissions from incinerators
Surface water	Not discussed	Level from landfills, surface impoundments, land treatment, chemical precipitation, incineration, fixation/stabilization, neutralization	Level from incinerator scrubber water and spills from landfills	Not discussed
Groundwater	Not discussed	Level from landfills, surface impoundments, land treatment, incineration, fixation/stabilization, distillation	Level from landfills	Level and duration from landfills
Soil	Not discussed	Not discussed	Not discussed	Not discussed
HUMAN EXPOSURE	Number of persons and level via air	Number of persons and level via air, surface water, groundwater	Number of persons and level via air, surface water, groundwater	Level and duration via air and groundwater
PLANT AND OTHER ANIMAL EXPOSURE	Discussed only	Not discussed	Not discussed	Not discussed
OTHER ENVIRONMENTAL IMPACTS	Not discussed	Not discussed	Not discussed	Discussed only--detected contamination in aquifer

7.2.1 Waste Characterization

Table 7-2 presents the data sources and approach used to characterize the waste streams, spills, or disposal sites for the eight RIAs. The CERCLA RIAs use reporting data to estimate the number of remediated sites or spills and to obtain other general information about these wastes. They do not attempt to specify the volumes and concentrations of chemicals in these wastes. Methods of remediation are discussed only in the context of compliance costs and are not used for the estimation of changes in health risks.

The RCRA RIAs use various data sources to generate estimates of the number and types of waste streams, the volume of the waste streams, and the concentrations of toxic chemicals in the waste. The number and types of waste streams were estimated from survey or industry data in most cases. The volume of each waste stream was determined in three different ways: extrapolated from survey data; by dividing total volume disposed by the number of waste facilities; and from the assumed capacity for each model facility based on engineering data. Chemicals present in the waste streams and their concentrations were estimated using existing waste stream data bases and deriving typical lists of chemicals and their concentrations for the waste streams of interest. Current disposal methods were either derived from survey data or assumed. Disposal methods used with the new regulations were determined by using the least-cost feasible method for each waste stream. Duration of waste disposal analyzed ranged from 20 to 30 years (the average lifetime of a landfill) to continuous.

7.2.2 Release, Fate, and Transport Models

For the six RCRA RIAs that generated quantitative exposure estimates, Table 7-3 presents the release, fate, and transport models used to determine the level of human exposure in air, groundwater, and surface water. A more detailed presentation of the release models is given in Appendix B, and of the fate and transport models in Appendix C.

The air release and transport models used are described in varying levels of detail in the RIAs. Standard algorithms are used for several different sources of emissions: incineration or boiler burning, landfills, surface impoundments, road oiling, and dumping. The parameters affecting the release

TABLE 7-2. WASTE CHARACTERIZATION

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Number of waste streams, spills, or remediated sites	Change in number of remediated sites attributable to new regulations; based on EPA reporting data and informed judgment	Number of each of 10 model facilities from: total amount of used oil going to each type of facility from previous estimates (Franklin Associates, PEDCo, etc.) divided by assumed use rate by each model facility from engineering data	Number of waste streams: to landfills--equal to the number of disposal facilities from EPA data, RIA Mail Survey or hazardous waste management system; to POTW--equal to number of facilities from PRA estimates	Number of spills--from EPA Region VII reporting data, adjusted for noncompliance based on informed judgment and extrapolated to national level via ratio Region VII to total U.S. production
Geographical distribution of waste streams, spills, or remediated sites	Extrapolated from EPA reporting data	Not estimated	Extrapolated from survey data and hazardous waste data management system for C and D landfills; assumed the same as D landfills for sludge landfills	Not estimated
Volume of waste stream or spill	Not estimated	Assumed equal size waste stream to each model facility; from previous estimates (Franklin Associates, PEDCo, etc.) from engineering data	Assumed equal size waste stream to each size disposal facility; based on total volume of waste disposed from EPA data	From EPA reporting data--distribution of sizes by fitting data to a lognormal distribution
Chemicals and their concentration in waste stream	General discussion of chemicals based on EPA reporting data; no concentration estimates	From Franklin Associates data based on analysis of 1,071 used oil samples by end use; regulations impact concentration of chemicals in waste in some cases	From EPA hazardous waste data management system for 25 waste streams; for each disposal method, determines chemicals and their concentrations as the weighted average of the 10 largest waste streams to that disposal method	General discussion from EPA list of 698 hazardous substances; no concentration estimates
Methods of waste disposal or cleanup	Not used for benefits analysis	Baseline regulations and new regulations--Franklin Franklin Associates and PEDCo data	Baseline regulations--small-quantity generator survey; new regulations--least cost feasible alternative	Not used for benefits analysis
Duration of disposal analyzed	Not used for benefits analysis	Continuous disposal but landfill life of 20 yr assumed	30 yr disposal	Not used for benefits analysis

(continued)

TABLE 7-2. WASTE CHARACTERIZATION (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Number of waste streams, spills, or remediated sites	Number of incinerators from EPA reporting data in hazardous waste data management system	Currently land disposed--from EPA 1981 RIA Mail Survey and 1984 Small-Quantity Generators Survey	Stocks and currently generated wastes--Technical Resources Inc. data	Solvent waste streams--from EPA 1981 RIA Mail Survey extrapolated to national level; assigned to nine categories based on size and exposure level
Geographical distribution of waste streams, spills, or remediated sites	Hazardous waste data management system	From 1981 RIA Mail Survey and 1984 Small-Quantity Generators Survey	From Technical Resources Inc. data	From EPA 1981 RIA Mail Survey
Volume of waste stream or spill	Case studies of 51 incinerators: capacity and utilization rates of incinerators	From survey data--used average volume for each waste type	From Technical Resources Inc. data--developed three generic waste streams	Based on survey data assumed: 8.1% 1.0×10^7 gal/yr 24.3% 5.0×10^5 gal/yr 67.6% 5.0×10^4 gal/yr
Chemicals and their concentrations in waste stream	Chemicals from trial burn data, case study reports and hazardous waste data management system; concentration in incinerated waste is assumed to be 10% carcinogens and 90% noncarcinogens	RIA Mail Survey data on waste form and EPA code--match codes with existing waste stream data from RCRA risk-cost analysis model; some assumptions necessary to fill in the gaps	EPA and Technical Resources Inc. data--for three generic waste streams	Two representative waste streams modeled; halogenated and nonhalogenated; each contains three most frequently reported chemicals in Mitre Corporation data; concentrations--weighted averages from Mitre data
Methods of waste disposal or cleanup	Baseline and new regulations--incineration	Baseline regulations--RIA Mail Survey (to land); new regulations--least-cost feasible alternative	Baseline regulations--assumed RCRA landfill; new regulations--assumed incinerated	Baseline regulations--RIA Mail Survey to landfills or surface impoundments; new regulations--least cost of incineration or recycling
Duration of disposal analyzed	Continuous disposal assumed	Continuous disposal assumed	Continuous disposal assumed	20 yr disposal

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS

Medium	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
AIR				
Release	Not estimated	From burning; percent organics removed from test data or engineering data From landfills; Shen model[a] for covered and uncovered cells From road oiling and dumping; Mackay model[a] for organics only	From POTWs; removal values from chemical literature	Not estimated
Fate	Not estimated	No degradation assumed	No degradation assumed	Not estimated
Transport	Not estimated	From burning in boilers; Hanna-Gifford area source dispersion model[b] From road oiling; Gaussian line source dispersion model[b] From incinerators, landfills, asphalt plant burning, storage leaks and dumping; Turner and Canady point source dispersion model[b]	From POTWs: Industrial source complex model implemented on EPA GEMs model[b]	Not estimated
Chemical, geologic, and climate input parameters	Not estimated	Typical values from the literature for model facilities	Typical values from the literature for 27 environmental scenarios (see Liner Location Model)	Not estimated

[a] For detailed description, see Appendix A.
[b] For detailed description, see Appendix B.

(continued)

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS (continued)

Medium	Incineration	Land ban	Dioxins	Solvents
AIR				
Release	From incinerators: assume conform to regulations--0.02% waste organics POHC and PIC; 180 mg/dscm particulates; 1.8 kg/h of 1% HCl in stack gas	From all sources: methods not described in report (reference to methods used in RCRA risk cost-analysis model[a])	From incinerators and landfill spills: methods not described in report (reference to methods used in RCRA risk cost-analysis model[a])	From landfills each year: Tucker model for covered waste[a] From surface impoundments each year: Tucker model[a] for uncovered wastes From incinerators and recycling: 0.02% and 0.21% of processed waste, respectively
Fate	No degradation assumed	No degradation assumed	No degradation assumed	No degradation assumed
Transport	Chronic exposures--EPA industrial source complex model;[b] short-term exposures--EPA screening model	Turner and Canady point source dispersion model[b]	Turner and Canady point source dispersion model[b]	Industrial source complex model implemented on EPA GEMs model[b]
Chemical, geologic, and climate input parameters	Typical values from the literature	Probability distributions based on data in literature (see Background Document for Comparative Risk Assessment)	Probability distributions based on data in literature (see Background Document for Comparative Risk Assessment)	Typical values from the literature

[a] For detailed description, see Appendix A.

[b] For detailed description, see Appendix B.

(continued)

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS (continued)

Medium	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
GROUNDWATER				
Release	Not estimated	From landfill: RCRA risk-cost analysis model[a]; from leaks and dumping--after evaporation and cleanup, 30%	From landfills, lined and unlined: liner location release model[a]	Not estimated
Fate	Not estimated	Chemical-specific decay rate in transport model	No degradation in landfill, chemical-specific decay rate in saturated zone	Not estimated
Transport	Not estimated	Wilson and Miller steady-state release model[b]	Unsaturated zone: McWhorter and Nelson wetting front model[b] new line. Saturated zone random walk particle tracking model[b]	Not estimated
Chemical, geologic, and climate data inputs	Not estimated	Typical values from the literature for model facilities	Typical values from the literature (see Liner Location Model) for 27 environmental scenarios	Not estimated

[a] For detailed description, see Appendix A.
[b] For detailed description, see Appendix B.

(continued)

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS (continued)

Medium	Incineration	Land ban	Dioxins	Solvents
GROUNDWATER				
Release	Not estimated	From landfill: method not described in report (reference to method used in RCRA risk-cost analysis model[a])	From landfill: method not described in report (reference to method used in RCRA risk-cost analysis model[a])	From 20 years in landfill: release rate = leachate quantity x solubility until all released to air or groundwater
Fate	Not estimated		Chemical-specific decay rate included in transport model	No degradation assumed
Transport	Not estimated	Wilson and Miller steady-state release model[b]	Wilson and Miller steady-state release model[b]	PLUME model[b]
Chemical, geologic, and climate data inputs		Probability distributions based on data from the literature (see Background Document for Comparative Risk Assessment)	Probability distributions based on data from the literature (see Background Document for Comparative Risk Assessment)	Typical values from the literature

[a] For detailed description, see Appendix A.

[b] For detailed description, see Appendix B.

(continued)

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS (continued)

Medium	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
SURFACE WATER				
Release	Not estimated	From scrubber water: 11.1% metals From leaking tanks and dumping: after cleanup and evaporation, 70% From road oiling: 100% metals, some organics	Not estimated	Not estimated
Fate	Not estimated	Chemical-specific decay rate in transport model	Not estimated	Not estimated
Transport	Not estimated	Loucks, Stedinger, and Haith transport model[b]	Not estimated	Not estimated
Chemical, geologic, and climate input parameters	Not estimated	Typical values from the literature for model facilities	Not estimated	Not estimated

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[a] For detailed description, see Appendix A.

[b] For detailed description, see Appendix B.

TABLE 7-3. RELEASE, FATE, AND TRANSPORT MODELS (continued)

Medium	Incineration	Land ban	Dioxins	Solvents
SURFACE WATER				
Release	Not estimated	From all sources: methods used not described in report (reference to methods used in RCRA risk-cost analysis model[a])	From landfill spills: methods used not described in report (reference to methods used in RCRA risk-cost analysis model[a]) Incinerator scrubber water: 1 ppm dioxins assumed	Not estimated
Fate	Not estimated	Chemical-specific decay rate coefficient included in transport model	Insignificant decay rate coefficient in transport model	Not estimated
Transport	Not estimated	Loucks, Stedinger, and Haith transport model[b]	Not described but Loucks, Stedinger, and Haith transport model[b]	
Chemical, geologic, and climate input parameters	Not estimated	Probability distributions based on data in literature (see Background Document for Comparative Risk Assessment)	Probability distributions based on data in literature (see Background Document for Comparative Risk Assessment)	Not estimated

[a] For detailed description, see Appendix A.

[b] For detailed description, see Appendix B.

rates vary according to the emission source. In all the RIAs, no breakdown of the chemical is assumed after release and during air transport. The transport models used vary according to whether a point source release or area source release is assumed.

Chemical, geologic, and climatic input parameters are needed for the estimation of the release and transport models. In two of the RIAs, available data are used to generate probability distributions for highly variable input parameters, and a Monte Carlo method is used to generate probability distributions of the exposure estimates. The other RIAs use "typical" point estimates of the input parameters.

The groundwater release and transport models used are also presented in Table 7-3. Two different types of release models are used. Three RIAs use the model developed for the RCRA Risk-Cost Analysis model. This model estimates a declining concentration of leachate over time. Furthermore, the leachate collected in the leachate collection system is assumed to contain the toxic chemical. The liquid portion of the waste does not contain toxic chemicals in this model. Thus, if a lined landfill does not leak until several years after disposal has ceased, a significant fraction of the toxic chemicals will have been removed by the leachate collection system. In contrast, the other two RIAs that estimate releases to groundwater use a leachate release model that assumes that the concentration of leachate remains constant at its solubility level and all of the toxic chemicals disposed in the landfill over its 20- to 30-year lifetime are available to be released to air or groundwater after the liner begins to leak. In other words, they assume that the leachate collection system removes only water and nontoxic substances from the landfill. This is a worst-case model. In this model also, the liquid portion of the waste is assumed not to contain toxic chemicals. These two release models have widely varying implications for estimated release rates from both lined and unlined landfills.

Most RIAs include a chemical-specific decay rate in the saturated transport models. None accounts for possible degradation of the chemicals in the waste disposal site or unsaturated flow zone.

Both numeric and analytic transport models are used to estimate the concentrations of the toxic chemicals in groundwater at various distances from the release site. In the solvents RIA, an analytic model is used, the PLUME model, that uses as inputs both annual release rate and duration of release. Average concentrations over time are estimated. Three of the other RIAs use the Wilson and Miller Steady State Release model, which assumes continuous releases of chemicals to the groundwater and estimates a single steady-state well-water concentration. One RIA uses a numeric model, the Random Walk Particle Tracking model. Such numeric models are able to generate estimates of concentration over time for different release durations, and can include more realistic hydrogeological conditions than the analytic models. As with the air models, two RIA's used available data to derive probability distributions for input parameters for the exposure models. The other RIAs use "typical" point estimates of such parameters.

Table 7-3 also presents the release, fate, and transport models for surface water. Only three RIAs estimated releases to surface water. Two use methods described in the RCRA Risk-Cost Analysis model but did not present details. One of these RIAs also assumes a certain concentration of dioxins in scrubber water discharged to surface water--at a level below the detection limit. All three RIAs use the Loucks, Stedinger, and Haith model to model transport in the surface water. Continuous release and instantaneous mixing are assumed. This transport model includes a chemical-specific decay rate parameter. Two RIAs generate probability distributions for the input parameters while the third uses "typical" point estimates.

7.2.3 Population Exposed

Table 7-4 presents the methods used to estimate the populations exposed through each medium.

The population exposed to releases in air is estimated using the EPA GEMs modeling system in four of the RIAs. In all these RIAs, the population living within a 0.4-km to 50-km radius is assumed to be exposed. Three of these four RIAs assume that only the population within a 45° sector is exposed. The fourth uses the total population. The Small-Quantity Generators RIA uses data on number of persons exposed to groundwater for the air population exposure estimates. These assume one-half of the persons within a 1-km radius are exposed. The Used Oil RIA assumes different population densities around the different model facilities.

TABLE 7-4. POPULATIONS EXPOSED

Medium	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
AIR				
Population exposed	Not estimated	Boiler burning: 0-50 km radius, New York City density population. Asphalt burning, landfills, incineration, storage leaks and dumping: $\leq$1 km radius, 137.5 persons/km^2. Space heater burning, unvented: 1 person for 12 hr exposed; vented: $\leq$1 km, 750 persons/km^2. Road oiling: $\leq$1 km, 12.5 persons/km^2	Used groundwater exposure number based on data collected from 177 Subtitle C facilities--131 persons/km^2 average population density; assume one-half of all persons within a 1-km radius are exposed	Not estimated
GROUNDWATER				
Population exposed	Product of: (1) probability of groundwater contamination--0.74 from EPA data for 210 highly serious sites; (2) probability of drinking groundwater--used State rural or urban patterns; and (3) minimum of the population within a 3-mile radius or the population of the municipality in which the site is located; generates average for each census region for 210 highly serious sites	Landfills, storage leaks, dumping: $\leq$1 km, medium density 137.5 persons/km^2	Based on data collected for 117 Subtitle C facilities--131 persons/km^2 average density near sites; assume half of those within a 1-km radius are exposed	Not estimated
SURFACE WATER				
Population exposed	Not estimated	Road oiling: $\leq$1 km, 12.5 persons/km^2. Asphalt plants, storage leaks, dumping: $\leq$1 km, 137.5 persons/km^2	Not estimated	Not estimated

(continued)

TABLE 7-4. POPULATIONS EXPOSED (continued)

Medium	Incineration	Land ban	Dioxins	Solvents
AIR				
Population exposed	U.S. 1980 Census data for each case study site for 20 rings around facility from 0.4-km to 50-km radius	Used EPA GEMs modeling system for actual hazardous waste sites from RIA Mail Survey; assumed wind blows 30% of time and 45° sector contaminated; generated probability distributions of number exposed for 20 rings from 0.4-km to 50-km radius	Used EPA GEMs modeling system for actual hazardous waste sites from RIA mail survey; assumed wind blows 30% of time and 45° sector contaminated; generated probability distributions for number exposed for 20 rings from 0.4-km to 50-km radius	Used EPA GEMs modeling system for typical facilities from RIA mail survey; assumed wind blows 30% of time and 45° sector contaminated for 20 rings from 0.4-km to 50-km radius; used to generate low, medium, and high average exposure estimates per unit emitted waste
GROUNDWATER				
Population exposed	Not estimated	Based on data collected for 117 Subtitle C facilities; assumed half of those within a 1-km radius are exposed; generated a probability distribution	Based on data collected for 117 Subtitle C facilities; assumed half of those within a 1-km radius are exposed; generated a probability distribution	Not estimated
SURFACE WATER				
Population exposed	Not estimated	Used data from a survey of community water systems; generated a probability distribution	Used data from a survey of community water systems; generated a probability distribution	Not estimated

Three of the RCRA RIAs use data collected for 117 Subtitle C facilities by EPA to estimate the population density in areas exposed to contaminated groundwater. Half of the people within a 1-km radius of the site are assumed to be exposed. A fourth RIA assumes that all those within a 1-km radius of the site are exposed to the contaminated groundwater. The CERCLA RIA, which estimated the exposed population for groundwater, derive their estimates using census data for 210 actual highly serious sites and assuming a 3-mile radius for exposure. This number of persons is multiplied by the probability of groundwater contamination at the site and the probability of groundwater being used as a source of drinking water.

Two of the RIA's use data from a survey of community water systems to estimate a probability distribution for the number of persons drinking surface water. The Used Oil RIA assumes that persons within a 1-km radius of the site of release are exposed.

7.2.4 Outputs of the Exposure Impact Analysis

Table 7-5 presents a summary of the outputs of the exposure impact analysis for the eight RIAs. These outputs form the key inputs for the estimates of health benefits attributable to exposure changes. The RIAs first estimate exposures associated with each relevant method of waste disposal using the methods described above and presented in Tables 7-1, 7-2, and 7-3. The numbers of wastes disposed by each method under the old and new regulations are also estimated and the two sets of estimates combined to generate estimates of exposures with both the old and new regulations. In most cases, steady-state average exposure levels are calculated and individual exposures of 70 years assumed. For the Small-Quantity Generators RIA, 30-year disposal in the landfills is assumed and moving average 70-year exposures calculated for the population turning 70 years of age each year after onset of exposure. For the Solvents RIA, 20 years' disposal via landfills or incineration are assumed and exposure durations until contaminant concentration exceeds the taste-odor threshold estimated as well as the average exposure level. However, for the health risk estimates, durations of 70 years at the average exposure level are assumed.

Concentrations of toxic substances in each medium are converted to a daily human dose (mg/kg/day) by making assumptions about breathing and water

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS

Human exposure	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
AIR				
Number of persons	Site-specific for sites affected by regulation; calculated state averages per site; extrapolated to national for estimated number of remediated sites	Not presented in RIA but estimated for each model facility	200 per site x number of sites for each disposal method analyzed	Not estimated
Human exposure calculated from release, fate, and transport models	Not estimated	Steady-state average for each model facility; exposure in mg/kg/day not presented	Steady-state for each disposal method; exposure in mg/kg/day given by air concentration mg/m^3 x 22 m^3/day ÷ 70 kg	Not estimated
Duration of exposure	Not estimated	Not estimated; assumed lifetime = 70 yr	Not estimated; assumed lifetime = 70 yr	Not estimated
Changes due to new regulations	All "baseline" people have zero or reduced exposure	Differing quantities of oil to each model facility; Therefore, differing number of model facilities	No waste to D landfills. More POTWs and C landfills	Not estimated

(continued)

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS (continued)

Human exposure	Incineration	Land ban	Dioxins	Solvents
AIR				
Number of persons	Site-specific for case studies; extrapolated to national level several alternative ways	Exponential distributions with means from 9 to 475,555 for 20 rings per site x number of sites	Not presented	Not estimated
Human exposure calculated from release, fate, and transport models	From hypothetical waste stream; exposure in mg/kg/day given by air concentration mg/m^3 x 20 m^3/day x 0.5 ÷ 70 kg	Steady-state from model wastes; exposure in mg/kg/day given by air concentration mg/m^3 x 17 m^3/day ÷ 65 kg	Not presented	From model waste streams; streams; exposure in mg/kg/day given by air concentration mg/m^3 x 22 m^3/day ÷ 70 kg
Duration of exposure	Not estimated; assumed lifetime = 70 yr	Not estimated; assumed lifetime = 70 yr	Not estimated; assumed lifetime = 70 yr	For 20-yr disposal: 20 years; but for health risk estimates, assumed lifetime = 70 yr
Changes due to new regulations	Back calculated	Change in number of streams to each waste disposal method	Change in methods of disposal from land to incineration	Change in methods of disposal from land to incineration or recycling

(continued)

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS (continued)

Human exposure	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
GROUNDWATER				
Number of persons	Site-specific; calculate State averages; extrapolate to national by ratio of remediation to sites	Not presented; estimated for each model facility	200 per site x number of sites for each disposal method analyzed; divided by 70 for number turning 70 each year	Not estimated
Human exposure calculated from release, fate, and transport models	Not estimated	Steady-state average for each model facility; exposure in mg/kg/day not presented	70-year moving average for each year for up to 400 yr from disposal; exposure in mg/kg/day given by water concentration mg/L x 2.0 L/day ÷ 70 kg	Not estimated
Duration of exposure	Not estimated	Not estimated; assumed lifetime = 70 yr	Total is maximum 400 yr or until all substance gone from landfill; individual is lifetime = 70 yr	Not estimated
Changes due to new regulations	All "baseline" people have zero or reduced expsoure	Changing quantities of oil to each model facility; therefore, changing number of model facilities	Subtitle D to Subtitle C landfills; more sludge landfills	Not estimated

(continued)

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS (continued)

Human exposure	Incineration	Land ban	Dioxins	Solvents
GROUNDWATER				
Number of persons	Not estimated	For each facility, two distributions, low and high; probability low 0.5, high 0.5; low--lognormal mean = 21, standard deviation = 36; high--lognormal mean = 30,399, standard deviation = 69,873	Not presented	Not presented
Human exposure calculated from release, fate, and transport models	Not estimated	Steady-state for each waste stream and disposal method; exposure in mg/kg/day given by water concentration mg/L x 2 L/day ÷ 65 kg	Not presented	From model waste streams; average exposure in mg/kg/day given by water concentration mg/L x 2,0 L/day ÷ 70 kg
Duration of exposure	Not estimated	Not estimated; assumed lifetime = 70 yr	Not estimated; assumed lifetime = 70 yr	For 20-yr disposal, from 1 to 2,238 yr, starting after 20-yr disposal period; but for health estimates, assumed lifetime = 70 yr; exposure ceases if water concentration greater than taste-odor threshold for chemical
Changes due to new regulations	Not estimated	Change in number of waste streams to each disposal method	Change in methods of disposal from land to incineration	Change in methods of disposal from land to incineration or recycling

(continued)

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS (continued)

Human exposure	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
SURFACE WATER				
Number of persons	Not estimated	Not presented; estimated for model facilities	Not estimated	Not estimated
Human exposure calculated from release, fate, and transport model	Not estimated	Steady-state average for each model facility; exposure in mg/kg/day not presented	Not estimated	Not estimated
Duration of exposure	Not estimated	Not estimated; assumed lifetime = 70 yr	Not estimated	Not estimated
Changes due to new regulations	Not estimated	Changing quantity of oil to each model facility; therefore, changing number of model facilities	Not estimated	Not estimated

(continued)

TABLE 7-5. OUTPUTS OF EXPOSURE IMPACT ANALYSIS (continued)

Human exposure	Incineration	Land ban	Dioxins	Solvents
SURFACE WATER				
Number of persons	Not estimated	Exponential distribution, = 20,167 x number of disposal facilities	Not presented	Not estimated
Human exposure calculated from release, fate, and transport models	Not estimated	For each waste stream and disposal method exposure in mg/kg/day: [water concentration mg/L x 2.0 L/day ÷ 65 kg] + [water concentration mg/L x 6.5 g fish/day x 10^{-3} x bioconcentration factor for fish ÷ 65 kg]	Not presented	Not estimated
Duration of exposure	Not estimated	Not estimated; assumed lifetime = 70 yr	Not estimated; assumed lifetime = 70 yr	Not estimated
Changes due to new regulations	Not estimated	Changes in number of waste streams to each disposal method	Change in methods of disposal from land to incineration	Not estimated

drinking rates, chemical retention rates, daily fish consumption, and body weight. Breathing rates assumed vary between 17 and 22 m^3/day. All RIAs assume a 2-liter/day water consumption. All except one RIA assume that all toxic chemicals in the air breathed are retained. The Incineration RIA assumes a 50-percent retention rate. For surface water exposure, 6.5 grams of fish per day is the standard assumption.

7.3 SUGGESTIONS FOR IMPROVEMENTS

This section offers a number of suggestions, which, if implemented, would improve the exposure impacts analyses of hazardous waste RIAs. We list below 10 suggestions for improving future RIAs. Each of the 10 suggestions is described in more detail in Sections 7.3.1 through 7.3.10.

1. The waste characterization step should be improved, especially determination of the chemicals and their concentrations in modeled waste streams.
2. A broader view of possible release pathways should be taken.
3. More realistic models to estimate releases to groundwater should be developed.
4. Explicit assumptions/estimation of duration of disposal, release, and exposure should be included.
5. More explicit estimates of the fate of the toxic chemicals in air, surface water, and landfills and groundwater should be generated and used as inputs in the release and transport models.
6. Transport models should be chosen that can model exposure from varying release rates and time durations.
7. More consistent methods of estimating the number of people exposed should be used.
8. More consistent choice of model input parameters and more extensive use of sensitivity/uncertainty analyses.
9. More realistic modeling of the actual timing, persons affected, and level of the expected exposure impact of a regulation promulgated in a given year.
10. Incorporation of products market impacts and trends for the affected industries into the analysis.

7.3.1 Improve Waste Characterization

A key factor in any RIA is the estimation of the number, volume, and toxic chemical concentrations of waste streams likely to be affected by the new regulations. Lack of sufficient data for toxic chemical identity and concentration is the main reason that the CERCLA RIAs do not include a quantitative benefits analysis. In the RCRA RIAs, toxic chemical identity and concentration are also determined using incomplete data. A common method for determining the identity of chemicals in the modeled waste is to use those chemicals that have been observed most frequently to be in similar waste streams. However, for the purposes of health risk analysis, it would be more appropriate to choose those chemicals that are known to be present in the waste streams and that are most likely to have harmful health effects. The probability of each waste stream including that chemical might also be estimated so that harmful effects will not be overestimated.

7.3.2 Consider all Release Pathways

To be sure of estimating all the health impacts of new regulations, releases of the toxic chemicals to all four media, air, surface water, groundwater, and soil should be estimated to the extent that they are likely to have a significant impact on human health. If quantitative estimates for certain exposure pathways are not made, the discussion of release routes should make it clear that the omission was because the health impacts would be insignificant and not because the analyst arbitrarily chose to exclude them.

7.3.3 Improve Modeling of Groundwater Release

The two types of groundwater release models used in the eight RIAs represent very different patterns of release of toxic chemicals to groundwater. The RCRA Risk-Cost Analysis model estimates most of the releases occurring in the first few years, whereas the Liner Location model estimates steady-state releases over a long period of time. Many factors need to be considered in developing a groundwater release model, including:

- Degradation of the toxic chemicals in the landfill
- Concentration of toxic chemicals in leachate
- Concentration of toxic chemicals in free liquids
- Total volume of leachate
- Volume of leachate collected in leachate collection system
- Content of leachate collected in leachate collection system
- Fate of leachate collected in leachate collection system.

The existing models have either ignored or made overly simplistic assumptions about some of these factors. For example, it is assumed in both models that the chemical does not degrade at all in the landfill. When analyzing the impact of linings on release rates, the leachate collection system is a key factor and its role should be modeled explicitly. Models estimating releases to groundwater should be reviewed carefully and an approach developed that explicitly deals with all the factors listed above as well as other relevant factors.

7.3.4 Estimate Duration of Disposal, Release, and Exposure

Because the goal of an RIA is to enable comparison of the costs and benefits of new regulations, it is important that a common basis be used for estimating these costs and benefits. The most logical approach is to choose a period of waste disposal, either 1 year or 20 or 30 years, and compute the costs and benefits attributable to the new regulations for that disposal period. For a given disposal period, duration of release to the different media should also be estimated explicitly for different disposal methods. For example, releases to air from incineration occur only during the disposal period, while releases to groundwater from landfills may occur for up to 200 years after the end of the disposal period. Based on the duration of release to the environment, the duration of exposure from the different routes and disposal methods should also be estimated explicitly.

7.3.5 Improve Estimates of Fate of Toxic Chemicals

The fate of toxic chemicals released to soil, air, surface water, and groundwater is not well modeled in the eight RIAs. The chemical data are available, in many cases, that allow for estimates or informed judgment about photolysis, biodegradation, and other chemical decay rates in different transport media. Such data should be included in release and transport models to minimize the extent to which the exposure estimates generated represent a worst-case scenario rather than a most likely scenario.

7.3.6 Use Flexible Transport Models

Transport models that are capable of modeling exposures from varying release rates and time durations should be used to determine duration of exposure for a given duration of release. For example, the Wilson and Miller Groundwater Transport model assumes a steady-state release whereas the PLUME and RANDOM WALK models are able to relate exposure levels and durations to release levels and durations. The latter models or other similar models should therefore be used in future RIAs.

7.3.7 Develop Consistent Method for Population Estimates

The RIAs analyzed vary greatly in the methods used to estimate the number of people exposed by route of exposure. Because this is a key variable in determining health effects, it might be useful for EPA to develop a methodology for population exposed to soil, surface water, and groundwater to complement the EPA GEMs Modeling System for air. In this way, a more consistent approach to this estimation would be encouraged for future RIAs.

7.3.8 Improve Choice of Input Parameter Values

The values of many input parameters need to be specified to estimate exposures. Although a discussion of the values of the input parameters used in the eight RIAs is beyond the scope of this report, it is apparent that there is little consistency between RIAs. For example, daily breathing rates assumed varied between 17 m^3 and 22 m^3. Examples of other input parameter values that varied among RIAs included thickness of landfill cover and soil porosity. Although uniformity in parameter estimates is not necessarily desirable or possible, all RIAs should include tables that list the values (or distributions) assumed for all input parameters so that the reader can easily compare the parameter values used in different RIAs. Sensitivity analysis should be used for a few key input parameters about which there is much uncertainty. It can provide simple and useful information about the impact of changes in individual input parameter values. Two RIAs responded to the variability in possible parameter values by using probability distributions for input values and generating probability distributions of the outputs. Full-scale uncertainty analysis should be used, only to the extent that the results can be presented in a way that improves the decisionmaker's ability to make informed judgments. The two RIAs that performed an uncertainty analysis by using probability distributions for input values and generating probability distributions for the output, presented only the mean estimates. Such analyses would be more useful if some statistics indicating the degree of uncertainty about the mean estimates were presented.

7.3.9 Present Realistic Estimates of Timing of Regulation Impact

Currently ignored in all but one of the RIAs (Small-Quantity Generators) reviewed are realistic estimates of the timing of exposure changes and the ages of the persons impacted for a regulation promulgated in a given year. For lifetime exposures to change from a higher level to a lower level as assumed in most of the RIAs, a 70-year transition period is necessary. During this period, there will be people alive who have been exposed to both levels for varying periods of time. So that more realistic assumptions can be included, the timing of exposure changes relative to the promulgation of the regulation should be estimated explicitly and the age distribution of the exposed population determined.

7.3.10 Incorporate Market Trends

None of the RIAs discuss the possible impact of high compliance costs on the volume of hazardous waste generated in future years. This should be included in the benefits analysis where appropriate. Finally, only one of the RIAs (Dioxins) made any attempt to incorporate overall market trends for the affected industries into the analysis. Such trends can have a major affect on the projected impact of a regulation over a multiyear period. For example, if generation of a hazardous waste is likely to decline in the future, the exposure impacts of the regulation will be less than if more hazardous waste is likely to be generated. Such market trends can be included in a multiyear analysis by projecting weights that can be used to estimate future waste stream quantities and thus future exposures.

SECTION 8

ESTIMATING BENEFITS

8.1 FRAMEWORK FOR ANALYSIS

This section of the RIA should start by presenting an overview of all the environmental impacts attributable to release of the toxic chemicals of interest via human exposure and other environmental contamination. Human health effects that should be estimated include cancer cases, reproductive and other major noncancer effects, and minor effects such as skin irritation, nausea, and headaches. Other environmental impacts that should at least be discussed, and should be estimated if time and data permit, include reduced availability of drinking water, reduced recreation opportunities, reduced aesthetics/ amenities (dirty houses, smelly air, etc.), and animal and plant kills.

8.1.1 Quantitative Estimates of Human Health and Environmental Effects for Baseline and Alternative Regulations

Quantitative estimates of the magnitude of all the environmental impacts identified should be obtained to the extent that data are available. In addition to the outputs of the exposure impact analysis, dose-response relationships or damage functions are key inputs. Such functions represent the relationship between the level and duration of exposure and the magnitude of adverse health and other harmful effects. Such relationships for health effects have been estimated by EPA from epidemiologic or toxicologic studies for many chemicals. In general, linear, no-threshold relationships have been postulated for carcinogens and nonlinear or threshold relationships for noncarcinogens. For both carcinogens and noncarcinogens, safety factors are built into EPA's estimates of Risk Specific Doses (RSDs) and Reference Doses (RFDs), respectively. The RSD represents the lower 95 percent confidence limit of the dose that, if experienced over a lifetime, will result in a specific excess risk of cancer, for example, one in a million, while the RFD represents the experimental no-effect level reduced by a safety factor of 10, 100, or 1,000 to give the largest dose that will not cause any harmful noncarcinogenic effects. The safety factors are included because of the uncertainty involved in extrapolating results between animal species and from high (experimental) to lower (environmental) doses.

In trying to compare waste disposal methods that might expose the population-at-risk for differing time periods, from 20 years to 200 years, it is necessary to have dose-response relationships that generate estimates of excess risks for all such exposure periods. Unfortunately, the data needed to determine such relationships are not available at this time. However, if assumptions are made as to the method of action of a carcinogen, it is possible to model the relationship for less than lifetime exposure using the data from lifetime exposure studies. The estimates for excess cancer cases for each disposal method could, therefore, reflect both the level and duration of exposure attributable to that method. Similarly, estimates of noncarcinogenic effects should be based on both level and duration of exposure if possible.

Damage-functions that relate contamination with nonhealth effects, such as reduced recreational opportunities, have been less frequently estimated. Such functions could be estimated using empirical or survey techniques.

A further threshold that should be considered for both carcinogens and noncarcinogens is the taste-odor threshold of the chemical. If the chemical is in the environment at levels at which it can be tasted or smelled, the contamination is likely to be detected and steps taken to prevent further exposure. Severe health impacts are thus likely to be avoided, while the community will incur significant remediation costs.

The exposure data and dose-response relationships can be combined to generate estimates of total numbers of cancer cases or other harmful health effects as well as average and maximum individual risks for these adverse effects both with and without the new regulations. Ideally, to be able to compare changes in health directly with changes in waste disposal costs, for example, we would like to measure the changes in common units--dollars. This could be done if dollar values could be derived for each of the harmful health effects experienced. Such dollar values would represent people's willingness-to-pay for a reduction in the risk of a cancer case or other harmful health effect. Estimates of the timing since onset of exposure of adverse health effects attributable to different disposal methods for the waste are also of interest especially as they compare with the timing of the waste disposal/remediation costs. If estimates are obtained of the timing of health effects valued in dollars, then discounted totals of the health effects can be obtained.

Nonhealth effects can be estimated using data from the exposure impacts analysis and damage functions. For example, the cost of aquifer cleanup and alternative water supplies when the groundwater is found to be contaminated might be estimated. The contamination might be detected if the concentration of the chemical is above its taste/odor threshold. The loss of surface water quality, and therefore its recreational value, might also be estimated. Such a loss can be valued using either a travel cost approach or a direct survey approach.

8.1.2 Estimation of Benefits

Once all the harmful effects attributable to release of the toxic chemical both with and without the new regulations have been estimated, the change in health and environmental effects attributable to regulation-induced changes in the toxic chemical release rate can be estimated. The most common measures of these changes are the changes in cases of harmful health effects and changes in the dollar impact of the other harmful effects, such as aquifer cleanup. For noncarcinogens, changes in person-years of exposure above the ADI might substitute for changes in number of cases of harmful health effects. Changes in individual risks can be informative, but only if accompanied by information on concurrent changes in the total number of people at risk of exposure. Sensitivity/uncertainty analysis should be performed for the results since many parameters are not well represented by a single-point estimate.

8.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 8-1 presents an overview of the analysis to estimate benefits attributable to changes in releases of toxic chemicals brought about by the new regulations for the eight RIAs. The two CERCLA RIAs discuss such benefits but perform no quantitative estimates. The six RCRA RIAs all generate quantitative estimates of cancer risks attributable to the toxic chemicals for various

TABLE 8-1. OVERVIEW OF HARMFUL ENVIRONMENTAL EFFECTS

Type of harmful effects	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Cancers	Discussed for typical chemicals but no quantitative estimates	Quantitative estimates for used oil use in 10 model facilities and national aggregates	Quantitative estimates for disposal in landfills and to POTW	Discussed very briefly
Other harmful health effects	Discussed for typical chemicals but no quantitative estimates--teratogenic, neurologic, gastrointestinal, toxic	Quantitative estimates for used oil use in model facilities	Quantitative estimates for disposal in landfills and to POTW	Discussed very briefly--teratogens and nontoxic irritating substances
Other harmful effects	Discussed but no quantitative estimates--recreation damage, property value declines, community development delays	Discussed very briefly but no quantitative estimates--productivity losses, cleanup costs, alternative water supply costs, damage to drinking water availability, visibility, and smell	Not estimated	Discussed very briefly--damages to plants and animals; damages to recreation, property value declines; aesthetic and productivity losses

(continued)

TABLE 8-1. OVERVIEW OF HARMFUL ENVIRONMENTAL EFFECTS (continued)

Type of harmful effects	Incineration	Land ban	Dioxins	Solvents
Cancers	Quantitative estimates for inhalation of air emissions from incinerators	Quantitative estimates for multiple disposal methods	Quantitative estimates for multiple disposal methods	Quantitative estimates for multiple disposal methods
Other harmful health effects	Estimates for potential to be above safe threshold level	Quantitative estimates for multiple disposal methods; weighted by severity factor	Not estimated	Quantitative estimates of level of exposure relative to ADI for multiple disposal methods
Other harmful effects	Not discussed	Not estimated; very briefly discussed	Not estimated	Not estimated; costs of switching to alternative water supplies once level above taste-odor threshold briefly discussed

disposal methods. Five out of six of these RIAs also generate quantitative estimates of noncancer risks attributable to the toxic chemicals for various disposal methods. None generates quantitative estimates of other harmful effects, although most discuss such effects and the Solvents RIA assumes exposure ceases when the water concentration is above the taste-odor threshold because people switch to alternative water supplies. The costs of such switching are not estimated, however.

8.2.1 Quantitative Estimates of Human Health and Environmental Effects for Baseline and Alternative Regulations

Table 8-2 presents the scope and methods of estimation of harmful effects for each regulatory alternative for the eight hazardous waste RIAs. For carcinogenic chemicals, all the RCRA RIAs use EPA estimates for the dose-response relationships. The EPA estimates represent a worst-case scenario for the risks of exposure and assume a linear relationship at environmental (low) doses. Four out of six RIAs estimate the number of excess cancer cases expected under the baseline and one or more regulatory alternatives. The Solvents RIA does not estimate total number of persons exposed and therefore cannot generate estimates of total cancer cases. The Incineration RIA only estimates total cancer cases under one regulatory alternate, compliance with the current regulations. Excess cancer cases are estimated as the product of number of persons exposed, level of exposure, and risk per unit dose. All the RIAs assume lifetime exposure. All except one assume a single exposed population cohort. The Small-Quantity Generator RIA assumes multiple exposed cohorts for groundwater exposure, based on the total duration of exposure. Four of the RCRA RIAs present estimates of maximum and/or average individual excess risk of cancer from lifetime exposure.

None of the RIAs explicitly estimates the timing of expected cancer cases relative to the time of exposure. In some cases the issue is briefly discussed. In these RIAs, the cancer cases are assumed to occur over the next 70 years and, in one RIA, over the next 400 years. None of the RIAs attempts to estimate or even discuss a dollar value that might be associated with a case of environmentally induced cancer. None of the RIAs attempts to discount the cancer cases and only one even discusses the issue of discounting health benefits.

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
CARCINOGENS				
Dose-response relationship	Not estimated	EPA dose-response functions	Linear, unit risks from EPA estimates	Not estimated
Total cancer cases	Not estimated	Yes from: $\sum_f N_f \sum_m C_{fm}$ where $C_{fm} = E_{fm} \times P_{fm} \times H$ and C_{fm} = number of cancers by medium per facility E_{fm} = exposure level by medium per facility P_{fm} = number of persons exposed by medium per facility H = unit risk factor N_f = number of model facilities nationwide	Yes from: $\sum_{t=1}^{400} R_t \times N_t$ where $R_t = H \times D_t$ and H = unit risk factor D_t = average 70-yr exposure level for persons turning 70 at year t N_t = number of persons turning 70 in year t = population-at-risk/70	Not estimated
Risk for maximally exposed individual	Not estimated	Not estimated	Yes from: $R_{max} = \max_t (H \times D_t)$	Not estimated
Risk for average exposed individual	Not estimated	Not estimated	Not estimated	Not estimated
Timing of cancer cases	Not estimated	Not estimated; assumed over next 70 yr	General discussion; over next 400 yr	Not estimated
Dollar value for cancer cases (morbidity, mortality)	Not estimated	Not estimated	Not estimated	Not estimated
Discounting of cancer cases	Not estimated	Not estimated	Not estimated	Not estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
CARCINOGENS (con.)				
Dose-response relationship	Linear, potency factors from EPA estimates--used median potency for all carcinogens reported in incinerated waste	Linear, unit risks from EPA estimates	Linear, unit risks from EPA estimates	Linear, unit risks from EPA estimates
Total cancer cases	Yes; for each case study facility from: number of persons x average exposure level x cancer risk/unit exposure aggregated to all facilities	Yes from: $\sum_{m}\sum_{s} R_{ms} \times N_{ms} \times S$ where $R_{ms} = H \times D_{ms}$ and H = unit risk factor D_{ms} = exposure level for medium N_{ms} = number of persons/medium/site S = severity weight (=1 for cancer)	Yes; but method not described (see Background Document for Comparative Risk Assessment)	Not estimated
Risk for maximally exposed individual	Yes; for each case study: = maximum exposure level x cancer risk/unit exposure	Not estimated	Yes; by medium and disposal method but method not described (see Background Document for Comparative Risk Assessment)	Yes; for halogenated waste stream by disposal method--maximum exposure level x unit risk factors
Risk for average exposed individual	Yes; for each case study (= average exposure level x cancer risk/unit exposure)	Not estimated	Yes; by medium and disposal method (see Background Document for Comparative Risk Assessment)	Yes; for halogenated waste stream by disposal method--average exposure level x unit risk factors
Timing of cancer cases	Not discussed	Assumed next 70 yr	Assumed next 70 yr	Discussed briefly; groundwater cases at least 30 yr later than air effects
Dollar value of cancer cases (morbidity, mortality)	Not estimated	Not estimated	Not estimated	Not estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
CARCINOGENS (con.)				
Sensitivity analysis for cancer cases	Not estimated	Performed uncertainty analysis for one storage facility using Monte Carlo simulation and probability distributions for input variables	Not estimated	Not estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE *(continued)*

Topic	Incineration	Land ban	Dioxins	Solvents
CARCINOGENS (con.)				
Discounting of cancer cases	Not estimated	Not estimated	Not estimated	No; but very briefly discussed
Sensitivity analysis	Sensitivity of estimates of cancer cases to method of extrapolation of case study results in national level presented	Not estimated	Not estimated	Briefly discussed via exposure impacts

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
NONCARCINOGENS				
Dose-response relationship	Not estimated	Threshold, environmenmental exposure limits from EPA	Quadratic with no threshold; unit risk from minimum effective dose (MED): $H = R_o/MED^2$ H = unit risk--probability of response/unit dose R_o = proportion of population affected at MED for dichotomous response = 1 for graded response	Not estimated
Cases of harmful effects	Not estimated	Estimated for lead only; method not presented	Yes; from: $\sum_{t=1}^{400} R_t \times N_t$ where $R_t = H \times S \times D_t^2$ and H = unit risk for noncarcinogen S = severity of harmful effect (0-1) D_t = average 70-yr dose for persons turning 70 at t N_t = number of persons turning 70 at t	Not estimated
Risk for maximally exposed individual	Not estimated	Not estimated	Yes; $\max_t (H \times S \times D_t^2)$	Not estimated
Risk for average exposed individual	Not estimated	Ratio of average exposure to environmental exposure limits estimated	Not estimated	Not estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
NONCARCINOGENS				
Dose-response relationship	Threshold; acceptable daily intake (RFD), threshold limit values, and environmental exposure limits from EPA data	Quadratic; no threshold unit risk from minimum effective dose (MED): $H = R_0/(MED)^2$ H = unit risk-probability of response/unit dose R_0 = proportion of population affected or MED for dichotomous response = 1 for graded resposne	Not estimated	Threshold; RFDs from EPA
Cases of harmful effects	Not estimated	Yes; from: $\sum_{m}\sum_{s} R_{ms} \times N_{ms} \times S$ where $R_{ms} = H \times D_{ms}^2$ and H = probability of response/unit dose D_{ms} = dose per medium per site N_{ms} = number of persons per medium per site S = severity weight (0-1)	Not estimated	Not estimated
Risk for maximally exposed individual	Comparison of maximum exposure to threshold levels to determine probability of adverse effects	Not estimated	Not estimated	Ratio of maximum exposure level to RFD estimated
Risk for average exposed individual	Comparison of average exposure to threshold levels to determine probability of adverse effects	Not estimated	Not estimated	Ratio of average exposure level to RFD estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
NONCARCINOGENS (con.)				
Timing of harmful effects	Not estimated	Not estimated	Generally discussed; over next 400 years	
Dollar value of harmful effects	Not estimated	Not estimated	Not estimated	Not estimated
Discounting of harmful effects	Not estimated	Not estimated	Not estimated	Not estimated
Sensitivity analysis	Not estimated	Not estimated	Not estimated	Not estimated

(continued)

TABLE 8-2. HARMFUL EFFECTS OF CHEMICALS UNDER EACH REGULATORY ALTERNATIVE (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
NONCARCINOGENS (con.)				
Timing of illness	Not estimated	Assumed for 70 yr	Not estimated	Not estimated
Dollar value of illness	Not estimated	Not estimated	Not estimated	Not estimated
Discounting of illness	Not estimated	Not estimated	Not estimated	Not estimated
Sensitivity analysis	Not estimated	Not estimated	Not estimated	Briefly discussed via exposure impacts

In three of the RCRA RIAs no sensitivity/uncertainty analyses for the estimates of cancer risks are performed. The Used Oil RIA demonstrates a method for performing uncertainty analysis using Monte Carlo simulation for one of its model facilities. The Incineration RIA presents estimates of the sensitivity of the cancer estimates to the method used to extrapolate from the case study results to national estimates. Finally, the Solvents RIA discusses the sensitivity of the cancer risk estimates to changes in estimated exposure impacts.

The dose-response relationships used for noncarcinogens vary among the five RIAs generating quantitative estimates for such chemicals. Three of these RIAs use the threshold values (e.g., RFDs) generated by EPA and compare the estimated exposure levels to these threshold levels for maximum and average exposed individuals. Two of the RIAs use a method developed for the Liner Location model where a quadratic, no threshold dose-response relationship is estimated using animal data. This relationship is combined with the outputs of the exposure impact analysis to generate estimates of the number of cases of noncarcinogenic health effects. A severity weight (between 0 and 1), where cancers and other serious, nonreversible health effects are given the value 1, and minor, reversible irritations the value 0.1, is applied to the estimate of number of cases in both these RIAs.

None of the RIAs specifically includes estimates of the timing of the nonhealth effects although in two cases comparable timing to that of the cancers is assumed. None of the RIAs attempts to estimate or discuss a dollar value associated with the harmful health effects and none attempts to discount the estimates. Only one RIA even discusses sensitivity analysis--the Solvents RIA discusses the sensitivity of the health effects to changes in the estimated exposure impacts. Finally, none of the RIAs presents any estimates of nonhuman health impacts or other nonhealth impacts of hazardous waste disposal or spills.

8.2.2 Estimation of Benefits

Table 8-3 summarizes the estimates of benefits attributable to the changes in releases of toxic chemicals likely to be induced by the new regulations being analyzed. The two CERCLA RIAs do not present any quantitative estimates of these expected benefits. Four of the six RCRA RIAs estimate the

TABLE 8-3. BENEFITS ESTIMATED

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Avoided cancer cases	Not estimated	Yes; assuming lifetime exposure at steady-state level	Yes; assuming total exposure spread over lifetime	Not estimated
Reduced cancer risk	Not estimated	Not estimated	Yes; assuming total maximum exposure spread over lifetime	Not estimated
Reduced other health effects	Not estimated	Estimated in one or two cases only	Yes; but increases estimated	Not estimated
Reduced risk of other health effects	Not estimated	Not estimated	Not estimated	Not estimated
Reduced number of persons-at-risk of exposure to toxic chemicals	Yes	Not presented	Not presented	Not estimated
Reduced other environmental damage	Not estimated	Not estimated	Not estimated	Not estimated

(continued)

TABLE 8-3. BENEFITS ESTIMATED (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Avoided cancer cases	No direct comparison of harmful effects under different regulatory alternatives	Yes; assuming lifetime exposure at steady-state level	Yes; assuming lifetime exposure at steady-state level	Not estimated
Reduced cancer risk	No direct comparison of harmful effects under different regulatory alternatives	Not estimated	Yes; assuming lifetime exposure at steady-state level	Yes; assuming lifetime exposure at average or maximum exposure levels
Reduced other health effects	Not estimated	Yes; assuming lifetime exposure at steady-state level	Not estimated	Not estimated
Reduced risk of other health effects	No direct comparison of harmful effects under different regulatory alternatives	Not estimated	Not estimated	Yes; reduced ratio of exposure levels to ADI
Reduced number of persons-at-risk of exposure to toxic chemicals	Not estimated	Not estimated	Not presented	Not estimated
Reduced other environmental damage	Not estimated	Not estimated	Not estimated	Not estimated

avoided number of cancer cases and three estimate the reduced cancer risk for exposed individuals. Three of the six RCRA RIAs estimate other health effects avoided and one estimates the reduced ratio of exposure to the threshold level. Although it must have been estimated as part of the calculations for some RCRA RIAs, none presented estimates of the reduction in size of the population exposed to releases of toxic chemicals from waste sites or spills. Such estimates were presented in one CERCLA RIA. None of the RIAs estimated reductions in other environmental damages. The Incineration RIA differed from the other RCRA RIAs in that it did not directly compare the health effects attributable to exposure under different regulatory alternatives.

8.3 SUGGESTIONS FOR IMPROVING RIAs

This section offers a number of suggestions which, if implemented, would improve the benefits analyses of hazardous waste RIAs. We list below nine suggestions for improving future RIAs. Each one is described in more detail in Sections 8.3.1 through 8.3.9.

1. When possible, estimate and present both total cases of harmful effects and individual risks, average and maximum.

2. For noncarcinogens, estimate total cases and individual risks if a dose-response function has been estimated, otherwise, estimate the person-years of exposure above the no-effect level and the ratio of the exposure level to the no-effect level.

3. Estimate nonhealth impacts of exposure changes.

4. Do not assume lifetime exposure to carcinogens unless appropriate to do so.

5. Present estimates of the timing of the harmful health effects relative to time of exposure, as well as estimates of the demographic characteristics of the persons most likely to be affected.

6. Discuss valuation of harmful health effects.

7. Discuss the discounting of harmful health effects.

8. Include the results of sensitivity/uncertainty analysis.

9. Demonstrate the importance of detection of contamination, either through bad taste or smell or routine testing, for avoiding harm to human health and the environment.

8.3.1 Present Cancer Cases and Individual Risk

In order to be able to determine whether a waste disposal method is protective of human health, it is important to have estimates of cancer risks both at the individual level and in aggregate. Thus, both these dimensions should be presented in all future RIAs that attempt to quantify health effects.

8.3.2 Estimate Person-Years of Exposure for Noncarcinogens

The types of harmful health effects other than cancer associated with exposure to a given toxic chemical should be discussed and the potential for varying levels of severity at different exposure levels explored. If possible, a dose-response relationship should be estimated that includes both increase in incidence and in severity with dose. This could then be used to estimate cases, severity, and duration.

If only estimated threshold doses are available, noncarcinogenic health effects should be specified in terms of their duration, level of exposure, and number of people exposed. Given estimates of the duration of exposure to the toxic chemical, we can directly project the duration of the harmful effect if it is reversible. Furthermore, since the severity of a noncarcinogenic effect may increase the more the exposure level exceeds the no-effect level, the ratio of the exposure level to the threshold level is a useful measure. This was included in two of the RIAs analyzed.

8.3.3 Estimate Nonhealth Impacts

The nonhealth impacts of exposure changes may be considerable and to exclude such effects from the quantitative analysis, as occurred in all the eight RIAs, seems unwarranted. In many cases the data for such estimates are readily available. For example, estimates of the costs of switching to alternative water supplies when one source is found to be contaminated can readily be determined from available data, recreational travel cost studies provide a data base for determining the dollar value of changes in water quality for recreation, and housing price studies can allow for estimation of the value of changes in the level of air pollution. Thus, the nonhealth impacts of exposure changes should be estimated in future RIAs. However, care should be taken to avoid double counting benefits. For example, property value studies may include valuation of the negative health effects.

8.3.4 Assume Realistic Exposure Durations for Carcinogens

All the RIAs analyzed assumed a lifetime exposure at a constant level to the toxic chemicals. However, depending on the duration of disposal being modeled, this is often not appropriate. For example, 20 years of disposal via incineration would only result in 20 years of exposure via the air near the incinerator. Moreover, the persons exposed typically are assumed to have an age distribution equal to that of the United States. Crump (1984) has shown that 20 years' exposure at age 20 does not have the same health impact as 20 years' exposure at age 50. Thus, the excess cancer cases attributable to any 20-year disposal period should be estimated using dose-response relationships that account for age and exposure duration. These are not available for most chemicals. The problem with ignoring these missing data and assuming lifetime exposures is that, for different disposal methods result in very different exposure durations, comparative analysis of these disposal methods will be biased. An alternative is to develop a hypothetical risk assessment model, based on available data, that allows for estimation of cancer risks for differing exposure durations (see Mauskopf 1985). As more data become available, more realistic models can be developed.

8.3.5 Estimate Timing of Harmful Effects

The timing of the harmful effects of exposure relative to time of exposure is also largely ignored in the eight RIAs analyzed. There is an important difference in timing for cancers and noncancers that should, at a minimum, be discussed; viz for cancers there is generally a long latency period (20 to 30 years) while noncancer effects can be experienced immediately. Detection of the toxic chemicals may occur if the health effects are severe or frequent. Such detection will be later for carcinogens relative to noncarcinogens because of the long latency period for cancer. The timing of the effect also determines the average age of the persons likely to be affected. The Mauskopf model (1985) mentioned above generates estimates of cancer cases that include information on timing after exposure and age of persons most at risk.

8.3.6 Discuss Valuation of Health Effects

So that the costs and benefits of new regulations can be compared directly, all costs and benefits should be estimated in common units--dollars. The dollar valuation of health effects is not even discussed in the eight RIAs analyzed, although a large literature exists on the topic and the EPA RIA guidelines describe appropriate methods that should be used to value both morbidity and mortality. At a minimum, the lack of such valuation should be noted. Alternatively, the RIA guidelines should be followed and dollar values applied to these health effects changes. A third approach would be to estimate threshold values for the health changes, at which values the benefits would just exceed the costs of the regulation.

8.3.7 Discuss Discounting of Health Effects

Discounting health effects that occur in the future is still controversial, although such discounting for future costs is generally accepted. Without estimates of the timing of health effects, discounting cannot be implemented. However, the comparison of discounted costs with undiscounted health effects should, at a minimum, include some discussion of the issue.

8.3.8 Perform Sensitivity Analysis

The results of the exposure impacts analysis and the dose-response relationships both are estimated with considerable uncertainty. Sensitivity analysis should be performed for the dose-response relationships and the exposure estimates to provide information about the impact of changes in these parameter values. Full-scale uncertainty analysis should be used only to the extent that the results can be presented in a way that improves the decision-maker's ability to make informed judgments.

8.3.9 Account for Taste-Odor Threshold

The final suggestion for improvement relates to the issue of detection of the contaminated air or water or soil. If the contamination is detected, action will probably be taken to prevent further exposure from taking place, thus minimizing the health impacts. The contamination may be detected because it tastes or smells distinctive. This possibility was taken into account in the Solvents RIA and exposure duration was estimated only for the period that the solvent concentrations were below their taste-odor threshold. All future RIAs should include estimates of the probability of detection for each year. This probability will depend on the taste-odor threshold of the chemical, its level at the points of human contact, the amount of routine or serendipitous testing, and the individual risk of harmful health effects at the exposure level. Based on this probability of detection, the harmful effects of hazardous waste disposal can be divided between effects when contamination is undetected and effects when contamination is detected. Both of these effects will be reduced by regulations that reduce the releases of toxic chemicals to the environment.

SECTION 9

ESTIMATING COSTS

9.1 FRAMEWORK FOR ANALYSIS

RIA cost analysis should strive to measure the costs of opportunities forgone due to a regulation. Individuals who bear costs are conveniently categorized into four groups--consumers, capital owners, employees, and taxpayers. All can be affected through changes in the prices (or taxes) they pay for goods or services or the prices they receive for labor and capital services. Costs can be subdivided into private real resource costs, deadweight consumer surplus costs, government regulatory costs, and factor displacement costs. The RIA should include a thorough discussion of all the costs that could be imposed by the regulations it is considering, including a discussion of who bears those costs.

9.1.1 Selecting a Cost Analysis Framework

Ideally, cost projections should follow directly from the product market impact projections discussed in Section 6. Costs are incurred partly as a result of changes in market prices and output rates, so their measurement should be based on such projections. Certain costs can readily be measured within such a framework; e.g., private real resource costs, deadweight consumer surplus costs, and, possibly, capital displacement costs. Other costs may be far more difficult (in practice) to measure in a market framework; e.g., employee displacement costs and government regulatory costs.

The decision as to which costs to project, as well as the framework for projecting them, should be discussed in the RIA. An explanation should be given for any costs not to be projected. Are they expected to be low, or are they impractical to project given resource constraints? It should be clear in the RIA's discussion of the cost framework that care is being taken to avoid double-counting of costs. For example, if a firm chooses to comply with a regulation and operate, real resource costs are borne by some combination of owners and consumers, depending on the length of run. If a firm chooses not to comply and operate, real resource costs are not borne. Employees and owners of capital may, however, incur displacement costs. As another example, real resource costs imposed on an intermediate products market may be passed through to buying markets. These costs should not be counted more than once, even though prices may increase in several markets.

An additional and very important consideration is the length-of-run underlying the cost analysis. On the demand side, consumers are better able, with the passage of time, to respond to price changes induced by regulations. Deadweight consumer surplus losses diminish as consumers identify satisfactory substitutes. On the supply side, factors of production such as capital and labor are more flexible in the long run than in the short run. Thus, displacement (adjustment) costs associated with a regulation affecting only new (as yet unconstructed) facilities should be less than those of a regulation imposed on existing and new facilities. The RIA should explicitly recognize such distinctions and the cost projections should reflect them.

9.1.2 Discounting Costs

Costs of hazardous waste regulations are typically incurred over a period of years. Given that costs are ultimately to be compared to benefits of regulation, a means is required to make the two comparable in light of temporal differences. Discounting is the usual method to accomplish this.

9.1.3 Cost Projections

Those costs that are projected in an RIA should be presented clearly, preferably in tabular form. When costs are incurred over time, it seems most useful to present costs year by year in constant, undiscounted dollars. Discounting should take place in the "Net-Benefits" chapter of the RIA.

Costs should be presented category-by-category as well as in total. It is advisable, in fact, to present costs as "not projected" for each category that is not projected. This technique makes it very explicit that the cost categories are recognized by the analysis but are not projected. This warns the reader that the projected total cost may be understated.

9.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 9-1 presents the definitions of costs and the analysis framework used for the eight RIAs. The framework for analysis suggests that costs of hazardous regulations should, at minimum, be discussed in an opportunity cost framework. Only two of the eight RIAs conscientiously address regulatory costs in this manner. One of the two, in fact, contains a discussion of real resource costs, deadweight costs, regulatory costs, and displacement costs. Other RIAs may mention one or two of the cost components, but not in a very thorough or systematic way.

9.2.1 Selection of a Cost Analysis Framework

Given that few RIAs discussed costs of the regulations in an opportunity cost framework, it is not surprising that few adopt such a framework to estimate those costs.

The Used Oil RIA does project real resource costs from the product market impact projections for price and output rate. It does not, however, project consumer deadweight costs and factor displacement costs as it might have.

None of the RIAs projects deadweight consumer surplus costs or factor displacement costs. Three of the RIAs do project regulatory costs.

Only one of the RIAs contains a discussion of the length-of-run being considered in the analysis.

9.2.2 Timing in Cost Analyses

The framework for analysis indicates that hazardous waste regulations frequently impose costs over a period of years. Cost analyses should specify for what year or years the costs are projected. It is clear that all of the RIAs project costs for a single year. However, only three of the RIAs indicate the year of analysis. Two of these RIAs explicitly indicate the year of analysis, and one does so implicitly by stating the year the regulation is assumed to be put in place.

9.2.3 Cost Projections

Table 9-2 evaluates the cost projections of the eight RIAs. The framework for analysis proposes that projected costs should be reported by category (real resource, deadweight, regulatory, and displacement) and in total. When

TABLE 9-1. IDENTIFICATION OF DIFFERENT TYPES OF COSTS AND SELECTION OF A COST FRAMEWORK

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
IDENTIFICATION OF DIFFERENT TYPES OF COSTS				
Real resource costs	Yes	Yes	No	No
Deadweight consumer surplus costs	Yes	No	No	No
Regulatory costs	Yes	No	Yes	Yes
Displacement costs	Yes	No	No	No
DISCUSSION OF COST BEARERS	Yes	Yes	Yes	No
SELECTION OF COST FRAMEWORK				
Real resource costs	Engineering cost approach	Engineering cost approach	Engineering cost approach	Engineering cost approach
Deadweight consumer surplus costs	None	None	None	None
Regulatory costs	Engineering cost approach; estimates from waste management officials	None	Engineering cost approach	Estimated from Resource Analysis Model for Superfund-engineering cost approach
Displacement costs	None	None	None	None
'Length-of-run' evaluation	None	Short-run choice discussed	None	None

(continued)

TABLE 9-1. IDENTIFICATION OF DIFFERENT TYPES OF COSTS AND SELECTION OF A COST FRAMEWORK (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
IDENTIFICATION OF DIFFERENT TYPES OF COSTS				
Real resource costs	No	No	No	No
Deadweight consumer surplus costs	No	No	No	No
Regulatory costs	No	No	No	No
Displacement costs	No	No	No	No
DISCUSSION OF COST BEARERS	No	No	No	No
SELECTION OF COST FRAMEWORK				
Real resource costs	Engineering cost approach	Engineering cost approach	Engineering cost approach	Engineering cost approach
Deadweight consumer surplus costs	None	None	None	None
Regulatory costs	None	None	None	None
Displacement costs	None	None	None	None
"Length of run" evaluation	None	None	None	None

TABLE 9-2. COST PROJECTIONS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
SINGLE- OR MULTIYEAR	Single	Single	Single	Single
YEAR OF ANALYSIS	Examines total appropriations from FY81-87	Heating season of 1986-87	Not specified	Not specified; data in 1983 dollars; rule to take effect 1985
PROJECTED COSTS				
Real resource[a] costs	Yes	Yes	Yes	Yes
Deadweight consumer surplus costs	No	No	No	No
Regulatory costs	Yes	No	Yes	Yes
Displacement costs	No	No	No	No

NA = Not applicable.

[a] The projected real resources costs in all but the Used Oil RIA are estimated engineering compliance costs.

TABLE 9-2. COST PROJECTIONS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
SINGLE- OR MULTIYEAR	Single	Single	Single	Single
YEAR OF ANALYSIS	Not specified	Not specified	Not specified	Not specified
PROJECTED COSTS				
Real resource costs[a]	Yes	Yes	Yes	Yes
Deadweight consumer surplus costs	No	No	No	No
Regulatory costs	No	No	No	No
Displacement costs	No	No	No	No

NA = Not applicable.

[a] The projected real resource costs are estimated engineering compliance costs.

costs of a particular type are not projected, they should be reported as "not projected."

Most of the RIAs project real resource costs as the estimated engineering compliance costs. None, however, projects deadweight costs to consumers or displacement costs that would be borne by workers or owners of capital. Three of the RIAs project regulatory costs.

None of the RIAs reports costs in tabular form for all categories, reporting those not projected as suggested.

9.3 SUGGESTIONS FOR IMPROVING RIAs

This section offers a number of suggestions which, if implemented, would improve the cost analyses of hazardous waste RIAs.

There are several practices that should be standard in all hazardous waste cost analyses, regardless of whether they are for Regulatory Impact Analyses of major rules or for lesser analyses of less costly rules. These practices should always be included because: (1) they are not costly to implement; and (2) they help to make the analytical process explicit. The suggested bare minimum requirements are:

- All potential costs of a hazardous waste regulation should be described along with the likely bearers of those costs; real resource costs, deadweight costs, regulatory costs, and factor displacement costs should all be addressed.
- The decision to project or not project each cost component should be explicit, as should the rationale for the decision.
- Costs that can be projected using the results of the market impacts analysis should be; other projection methodologies should be clearly explained.
- The length-of-run underlying the analysis should be clearly documented, as should the year (or years) of analysis.
- The timing of the costs should be openly discussed, as should the issue of discounting; the discounting itself, however, should be left to the benefit/cost comparison section.
- Cost projections should be clearly tabulated by category and in the aggregate; costs that are not projected should nonetheless be tabulated.

Private real resource costs should always be projected. They are usually the largest component of total cost and at the same time can be projected in a straightforward fashion using cost-engineering data and simplifying assumptions.

The importance of projecting other costs will vary greatly from case to case. The magnitudes of deadweight costs and displacement costs are both influenced largely by the magnitude of output rate impacts. As a rule, large relative output impacts will result in high deadweight and displacement costs. Caution must be exercised, however. A 1-percent reduction in output from an industry employing 80,000 workers will be more costly than a 5-five percent reduction in output from an industry employing 10,000 workers. Consequently, both relative and absolute impact projections should be considered.

When deadweight and/or displacement costs are projected, the following practices are recommended:

- Deadweight costs should be projected using the results of price and output rate impacts from the impacts model (see Section 6).
- The methodology used to estimate costs of worker displacements should be based on willingness-to-pay principles to the extent feasible.
- Capital displacement cost projections should take into account the value of displaced capital in other uses.

Regulatory costs should be projected when they are likely to be significant either absolutely or relative to real resource costs. To the extent practicable, they should be measured in an opportunity cost framework.

SECTION 10

COMPARISON OF COSTS AND BENEFITS

10.1 FRAMEWORK FOR ANALYSIS

Once the costs and benefits associated with the various alternative potential regulations have been estimated, a table should be prepared that presents both the benefits and the costs for each alternative. If possible, estimates of net-benefits or cost-effectiveness ratios should be computed from these results. If a single estimate of cost per harmful health effect avoided is to be generated, it should be recognized that health effects vary in severity and some sort of weighting system should be used before combining the estimates of numbers of cancer and noncancer cases. Net benefits can be estimated only if dollar values have been assigned to each harmful health effect. It is also essential, if meaningful cost-benefit comparisons are to be derived, to have cost and benefits estimates that refer to the same time period of waste disposal. Comparisons of 1-year waste disposal costs and benefits based on lifetime (70-year) steady-state continuous waste disposal cannot be compared meaningfully. Discounting should be applied to both future costs and benefits and a discussion included as to whom the benefits accrue and who bears the costs. The timing of the costs and the benefits are likely to be important factors here.

10.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 10-1 presents a summary of comparisons of the costs and benefits attributable to new regulations for the eight RIAs. In general, for compliance cost estimates, capital costs are annualized using a 10-percent discount rate. These annualized capital costs are added to the annual operating costs to generate total annual cost estimates. The quantitative health effects estimates are not discounted in any of the RIAs even though they may occur only after a long time lag. The compliance cost estimates are based on a 1-year period of waste disposal and the health effects estimates are based

TABLE 10-1. COMPARISON OF COSTS AND BENEFITS

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
DISCOUNT RATES				
Costs	None used	6 percent for annualized costs	Annual costs estimated	Annual costs estimates
Benefits	None used	None used	None used	None used
WASTE STREAM GENERATION TIME ASSUMED FOR				
Costs	7 yr	1 yr	1 yr	1 yr
Benefits	7 yr	Continuous	30 yr for landfills; continuous for volatilization from POTW	Not estimated
NET MONETIZED BENEFITS	Not estimated	Not estimated	Not estimated	Yes; but for changes in compliance-related outcomes only
COST-EFFECTIVENESS RATIOS	Not estimated; general discussion and tabular listing of costs (quantitative estimates) and benefits (qualitative list)	Annual costs per case of cancer avoided estimated from lifetime exposure cancer cases by dividing by 70; given for four regulatory alternatives	Not estimated; general discussion for proposed and alternative regulations, but no tabular listing of costs and benefits	Not estimated
PERSONS IMPACTED BY				
Costs	Costs to regulated parties and costs to governments estimated	Not discussed	Not discussed	Costs to regulated parties and costs to government estimated
Benefits	Discussed	Not discussed	Not discussed	Discussed briefly

(continued)

TABLE 10-1. COMPARISON OF COSTS AND BENEFITS (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
DISCOUNT RATES USED				
Costs	None used	Annual costs estimated	Annual costs estimated	Annual costs estimated
Benefits	None used	None used	None used	None used
WASTE STREAM GENERATION TIME ASSUME FOR				
Costs	One-time upgrading costs plus annual increase in operating and maintenance costs	1 yr	One time for stocks of waste; 1 yr for ongoing wastes	1 yr
Benefits	Continuous	Continuous; but landfill life 20 yr	Continuous for ongoing wastes; benefits not estimated for stocks	20 yr
NET MONETIZED BENEFITS	Not estimated	Not estimated	Not estimated	Not estimated
COST-EFFECTIVENESS RATIOS	No comparison of cost and benefits; cost estimates for complying with current regulation only; health effects assuming compliance with current regulation or assumed for risk-based variance regulation	Not estimated; no discussion	Not estimated; some discussion of cost-effectiveness of proposed and alternative regulations	No estimate of $/cancer case but percent reduction in cancer risk or noncarcinogen exposure ratio compared with percent increase in costs
PERSONS IMPACTED BY				
Costs	Not discussed	Not discussed	Not discussed	Not discussed
Benefits	Not discussed	Not discussed	Not discussed	Briefly discussed in context of release timing differences between disposal methods

either on a 20- to 30-year or a continuous lifetime disposal period, with no distinction made between disposal methods in most cases.

One of the RIAs estimates net-monetized benefits but for changes in compliance costs only. The rest of the RIAs do not generate estimates of net-monetized benefits because health effects are not assigned a monetary value. However, in most cases some cost-health effectiveness comparisons are attempted. These vary in their degree of quantification and in their clarity. In the Used Oil RIA, the ratio of annual dollar costs of the regulation to the annual number of avoided cancer cases is calculated. Annual avoided cancer cases are assumed equal to the avoided cancer cases for a single population cohort divided by 70. These ratios are used to compare regulatory alternatives. In the Contingency Plan RIA, although quantitative health effects are not generated, a useful tabular listing of costs and benefits is presented and discussed. The Small-Quantity Generators and Dioxins RIAs discuss the relationship between costs and benefits for different regulatory alternatives, but no attempt is made to quantify the relationship and no table is presented. The Solvents RIA presents a comparison of the percentage reduction in cancer risks or non-carcinogenic exposure ratio and percentage increase in compliance costs. The Incinerator RIA does not compare costs and benefits at all. The costs estimated are those associated with the compliance costs to move existing incinerators into compliance with the current regulations. Benefits are not estimated, only health risks when complying with the current regulations and the health risks mandated by a possible alternative regulatory approach.

The persons enjoying the benefits and suffering the costs attributable to the new regulations are not explicitly identified in most of these summary chapters for the RIA.

10.3 SUGGESTIONS FOR IMPROVING RIAs

This section offers a number of suggestions which, if implemented, would improve the cost-benefit comparisons of hazardous waste RIAs. We list below three suggestions for improving future RIAs. Each one is then described in more detail in Sections 10.3.1 to 10.3.4.

1. The RIA should compare nonvalued health effects and dollar costs or benefits for comparable durations of disposal.

2. The RIA should include a discussion of which population groups experience the costs and benefits.
3. The costs and benefits should be presented in a single summary table.

10.3.1 Compare Benefits and Costs for Same Duration of Disposal

Comparisons of nonvalued health effects with other dollar costs or benefits should be made for comparable durations of disposal. Annual costs, for example, should be compared to the change in health effects attributable to a single year of waste disposal. If this is not done, such cost-effectiveness estimates will be misleading for decisionmakers.

10.3.2 Discuss Population Groups Affected

Some discussion should be included in the summary or concluding chapter of the RIA of the population groups experiencing the costs and benefits of the regulations. This gives the decisionmaker more complete information on the impact of the alternative regulations.

10.3.3 Present Comparisons in a Table

In order to give the decisionmaker information in a useful format, the comparison of costs and benefits should be presented in a table as well as being discussed in the text. Both qualitative and quantitative estimates of these costs and benefits should be presented in this table so that the decisionmaker can make his/her own judgment about whether the unquantified costs or benefits are likely to be of sufficient importance as to change the decision he/she might make on the basis of the quantitative estimates alone.

SECTION 11

THE RIA AS A WHOLE

11.1 FRAMEWORK FOR ANALYSIS

The EPA Guidelines suggest that sufficient detail be given in either the RIA text or appendixes so that the estimation of benefits and costs is reproducible by the reader without the need to consult other documents. Thus, the RIA should include details of all estimation methods in a series of appendixes, as well as briefly describe these methods in the text.

The main goal of the RIA is to provide decisionmakers with a comprehensive assessment of the implications of alternative regulatory actions, especially with regard to the comparison of the benefits and costs of such actions. Thus, in addition to being a stand-alone document, the RIA should present a direct comparison of benefits and costs for a comparable duration of waste disposal or spill control. This should be accompanied by discussion of the persons incurring the benefits and costs, geographically, demographically, and over time.

Finally, the RIA should be clearly and concisely written, the type should be clear, and judicious use should be made of titles and subtitles. A complete bibliography of all data and model sources should be included.

11.2 COMPARATIVE ANALYSIS OF EIGHT RIAs

Table 11-1 presents the comparative analysis of the eight RIAs. In general, the eight RIAs analyzed were more complete in their description of the methodology used to estimate costs attributable to compliance activities than that used to estimate benefits attributable to changes in release of toxic chemicals. Thus, although the cost estimates could be reproduced by the reader from the RIA alone, in most cases this was not true for the benefits estimates.

The CERCLA RIAs were not well-balanced in that quantitative estimates of benefits were not attempted. Four of the six RCRA RIAs included too much

TABLE 11-1. THE RIA AS A WHOLE

Topic	Contingency plan	Used oil	Small-quantity generators	Reportable quantities
Full description of methods used	Yes	Yes	Yes for costs; no for benefits	Yes
Technical materials in appendices	Yes	Yes	Yes for costs; no for benefits	Yes
Results reproducible by reader from RIA alone	Yes	Yes	Yes for costs; no for benefits	Yes
Well-balanced document	Yes, except quantitative analysis of costs but not from benefits	Yes	No, too much general discussion, too little clear description of analysis	Yes, except quantitative analysis of costs but not benefits
Cost-benefit comparisons in useful format	Useful table, but comparison of alternative new regulations not included	Useful table presenting cost-effectiveness ratios for all alternatives	None given	Table for costs only. No discussion of fact that regulation is structured such that increased releases will be for less hazardous substances only
Physical layout	Good	Used a hard-to-read type, otherwise good	Used a hard-to-read type. Subheadings not numbered. Tables at end of chapter are hard for reader	Good

(continued)

TABLE 11-1 THE RIA AS A WHOLE (continued)

Topic	Incineration	Land ban	Dioxins	Solvents
Full description of methods used	Yes	Yes for costs; not in all cases for benefits, e.g., waste characterization	Yes for costs; none for benefits	Yes for costs; in most cases for benefits
Technical materials in appendixes	Not always--some in text	No for costs; not in all cases for benefits	No appendixes	No appendixes
Results reproducible by reader from RIA	Yes for costs; not in all cases for benefits	Yes for costs; in most cases for benefits	Yes for costs; no for benefits	Yes for costs; in most cases for benefits
Well-balanced document	Too much engineering and survey summary data, and philosophy of risk assessment. Not enough simple description of analysis method	No, too much general discussion, too little clear description of analysis	No, too much general discussion, too little clear description of analysis; no description of benefits methods	No, too much general discussion, too little clear description of analysis; technical materials should have been placed in appendixes
Cost-benefit comparisons in useful format	No, costs estimated for moving from current situation to compliance with current regulations. Benefits not explicitly estimated. Implicitly estimated for change from compliance with current regulations to risk-based variance approach	None given	No, discussion is inadequate	Compares percent change in costs to percent change in benefits. Duration of disposal assumed different for costs and benefits
Physical layout	Good type, but very confusing mix of separate reports and appendixes and too many "list" tables	Used a hard-to-read type; subheadings not numbered; tables at end of chapter are hard for reader	Used a hard-to-read type; subheadings not numbered; tables at end of chapter is hard for reader	Used a hard-to-read type; subheadings not numbered; tables at end of chapter are hard for reader

general discussion of the issues and too little clear description of analysis methods, parameter assumptions, and results. One of the other RCRA RIAs included too much engineering and survey data in the text.

Very few of the RIAs presented the cost-benefit comparisons in a format that might be useful for a decisionmaker. This was mostly the result of inappropriate modeling of these changes in the rest of the RIA as follows: Care had not been taken to generate estimates of costs and benefits for the same disposal period; no explicit estimates had been made of the timing of health effects after disposal; and no attempt had been made to value the health effects. Therefore, direct comparison of costs and benefits was not possible. The attempts made did not acknowledge these three fundamental reasons for their inadequate performance.

The physical layout of the RIA makes an enormous difference to the reader. The two CERCLA RIAs used a clear type, numbered subheadings, and included the tables in the body of the chapter. In contrast, four out of six of the RCRA RIAs used a hard-to-read type, did not number subheadings, and placed the tables at the end of the chapter--making them very hard to read.

11.3 SUGGESTIONS FOR IMPROVING RIAs

This section offers a number of suggestions that, if implemented, would improve the hazardous waste RIAs as a whole. We list below six suggestions for improving future RIAs. Each of the six suggestions is then described in more detail in Sections 11.3.1 through 11.3.6.

1. Include a full description of all methods used, putting technical materials in appendixes.
2. Include tables listing assumed input parameters for each estimation model.
3. Include a complete bibliography.
4. Include only a minimum amount of background discussion material.
5. Present benefit-cost comparisons for all new regulatory alternatives in a tabular and discussion format.
6. Use an easy-to-read type, number subheadings, and place tables within the text.

11.3.1 Make RIA a "Stand-Alone" Document

Since the methods used for performing cost-benefit analyses for hazardous waste regulation are not standardized, it is important for all methods used to be described clearly. Equations should be presented in appendixes where appropriate. The results of each stage of the analysis should be presented in tabular form (e.g., waste characterization, release rates, and exposure concentrations) so that the reader can easily follow the steps of the estimation process. References to supporting documents cannot substitute for such detail within the RIA document, even if the bibliographical reference is complete. The supporting document may not be readily obtainable (we speak from experience).

11.3.2 Present Input Parameter Values in Tables

To complement the complete discussion of methods of analysis, there should be a complete discussion of the choice/derivation of input parameter values. This discussion should be accompanied by tables listing the input parameter values used in each estimation model. Discussion of input parameters in the text without such tabular presentations places too great a burden on the reader and should be avoided in all future hazardous waste RIAs.

11.3.3 Include a Complete Bibliography

References to supporting documents or other published or unpublished sources should be included in a bibliography at the end of the RIA. Lack of completeness in this bibliography can be a source of great frustration for the reader who wishes to follow up a particular method or parameter derivation in greater depth.

11.3.4 Include Only a Minimum of Background Discussion

An RIA, if it is to be a complete document, must include some discussion of the background to the regulations, the current and alternative regulations themselves, the industrial context, and technical descriptions of disposal method. However, the main purpose of an RIA is to perform cost-benefit analyses for the new regulations. The more general issues should only be discussed briefly in the text to set up the framework for the cost-benefit analysis. If more detailed discussion seems necessary (e.g., for the derivation of input parameter values), it should occur in an appendix. For example, only the summary of data derived from the industry profile should be included in the text. The industry profile should be presented in an appendix. The main focus of the text of the RIA should be on the actual benefit-cost analysis. General discussion should be kept to a minimum throughout. Clear, concise, and sufficiently detailed discussions of the analytic methods should constitute the bulk of the text of all future hazardous waste RIAs.

11.3.5 Present Benefit-Cost Comparisons in a Table

For the benefit-cost comparisons to be useful to the decision-maker, they should be based on a single assumed duration of waste disposal. The comparisons should be presented in a tabular format for each of the regulatory alternatives being analyzed. The tables should include a listing of the main population groups experiencing the costs and benefits. The text written to accompany this table should provide a summary of the results of the RIA.

11.3.6 Use an Easy-to-Read Physical Layout

A document is written to be read. For this reason, an easy-to-read type should be chosen. If single spacing is used, a small type is easier to read than is a large type because it leaves more space between the lines. If a large type is used, double spacing is essential. Headings should be clearly visible and numbered to help give the reader an ongoing sense of the shape of the chapter. Finally, tables should be included in the text where they are first mentioned. Including them at the end of the chapter is very difficult for the reader.

SECTION 12

SUMMARY OF SUGGESTED IMPROVEMENTS

In this report we have presented a suggested framework for each major component of an RIA and performed a comparative analysis of eight hazardous waste RIAs to see how well they follow this framework. Based on these two steps, we present a summary of the specific suggestions presented throughout the report of ways in which hazardous waste RIAs might better achieve EPA's objectives in the future. These suggestions are summarized under 12 headings.

12.1 BROADER PERSPECTIVE

The adverse effects of the releases of hazardous substances, in addition to health effects, should be discussed and, where possible, estimated. For example, if contaminated well water is detected, the health effects may be zero, but the costs of alternate water supplies and aquifer cleanup may be large. However, care must be taken to avoid double counting of adverse effects.

Releases to all relevant media should be estimated as well as all relevant routes of exposure from each medium. Thus, media or exposure routes should be omitted from the benefits estimates only if their effects are likely to be insignificant.

12.2 QUANTITATIVE ANALYSIS OF SEVERAL ALTERNATIVES

Future RIAs should generate quantitative estimates of benefits and costs for the proposed regulation and at least one regulatory alternative. The regulatory alternatives analyzed should represent significantly different approaches compared with the proposed regulation. These alternatives should be selected from those that have been considered during the regulatory development process. To the extent that only a narrow range of options was considered during regulatory development, the RIA will necessarily have a narrower scope.

12.3 DERIVATION/PRESENTATION OF INPUT PARAMETER VALUES

Data sources should be described clearly and references included where appropriate. Survey data are a good, reliable source of data from industry. In RIAs that rely more heavily on reporting data, discussions of the limitations of that data and the likelihood and extent of under- or overreporting should be included. In RIAs that use estimates provided by a subcontractor, the primary data sources, whether industry sources, engineering estimates, or informed judgment, should be indicated so that the degree of certainty about the estimates may be ascertained.

Input parameter values should be tabulated for each estimation model used. Although uniformity in parameters estimates is not necessarily desirable or possible, all RIAs should include tables that list the values (or distributions) assumed for all input parameters so that the reader can easily compare the parameter values used in different RIAs.

12.4 METHODS FOR COST ESTIMATES

The effects of the regulation on the products markets should be described in an economic framework. For example, a supply/demand framework might be used.

The estimation method chosen should be selected on the basis of clearly defined decision rules. For example, such decision rules might be derived using a simulation approach to determine when the true costs of the regulation are likely to be misrepresented significantly by the more simplistic models. The degree of misrepresentation might depend on the magnitude of the compliance costs relative to total industry costs and the elasticities of supply and demand in the products markets.

Cost estimates should include a broader definition of costs than industry compliance costs. For example, the degree to which these costs are passed on to the consumer as higher product prices should be estimated. Also, costs due to unemployment and dislocation of capital should be estimated.

12.5 PRODUCTS MARKETS TRENDS AND EXPOSURES

The regulation's compliance costs may change the volume of hazardous waste generated in future years. Such changes may change exposures and should be discussed and estimated if likely to be significant.

Some attempt should be made to incorporate into the analysis overall market trends for the affected industries. Such trends can have a major effect on the projected benefits and costs of a regulation over a multiyear period. For example, if generation of a hazardous waste is likely to decline in the future for reasons other than the regulation, the cost and exposure impacts of the regulation will be less than if more hazardous waste is likely to be generated.

12.6 RELEASE, FATE, AND TRANSPORT MODELS

Use or develop transport models that allow variability in both level and duration of releases. For example, the Wilson and Miller Groundwater Transport model assumes a steady-state release whereas the PLUME and RANDOM WALK Groundwater Transport models are able to estimate exposure levels and durations that result from variable release levels and durations. The latter models or other similar models therefore should be used in future RIAs.

Make more realistic assumptions for models estimating releases of toxic chemicals from landfills for: degradation of the toxic chemicals in the landfill, concentration of toxic chemicals in leachate, concentration of toxic chemicals in free liquids, total volume of leachate, volume of leachate collected in leachate collection system, content of leachate collected in leachate collection system, and fate of leachate collected in leachate collection system. The existing models have either ignored or made overly simplistic assumptions about some of these factors (for example, no degradation of the chemical in the landfill). Models estimating releases to groundwater should be reviewed carefully by EPA and an approach developed that deals explicitly with all the factors listed above as well as other relevant factors.

12.7 PEOPLE AFFECTED BY THE REGULATION

Distinguish between people affected by compliance activities and people affected because of changes in releases of the toxic chemical. Among those affected by compliance activities, include a discussion of the relative importance of business owners, employees, and consumers.

Develop a more consistent methodology for estimating the number of people exposed to contaminated groundwater, surface water, and soil. The RIAs analyzed vary greatly in the methods used to estimate the number of people exposed by route of exposure. Because this is a key variable in determining health effects, it might be useful for EPA to develop a methodology for population exposed to soil, surface water, and groundwater to complement the EPA GEMs Modeling System for air. In this way, a more consistent approach to this estimation would be encouraged for future RIAs.

12.8 REALISTIC TIMING

Choose a common period of waste disposal for the estimates of benefits and costs. Because the goal of an RIA is to enable comparison of the benefits and costs of new regulations, it is important that a common basis be used for estimating these benefits and costs. The most logical approach is to choose a period of waste disposal--either 1 year or 20 to 30 years--and compute the benefits and costs attributable to the new regulations for that disposal period. For a given disposal period, duration of release to the different media should also be estimated explicitly for different disposal methods. For example, releases to air from incineration occur only during the disposal period, while releases to groundwater from landfills may occur for up to 200 years after the end of the disposal period. Based on the duration of release to the environment, the duration of exposure from the different routes and disposal methods should also be estimated explicitly.

Discuss and present estimates, if possible, of the timing of the harmful health effects relative to time of exposure. There is an important difference in timing for cancers and noncancers that should, at a minimum, be discussed; viz for cancers there is generally a long lag time after exposure (20 to 30 years) while noncancer effects may be experienced immediately. The lag time of the health effect determines the average age of the persons likely to experience the harmful health effects.

12.9 VALUATION OF HEALTH BENEFITS

Dollar valuation of health benefits should, at a minimum, be discussed in future RIAs. A large literature exists on the topic, and the EPA RIA guidelines describe appropriate methods that can be used to value both morbidity and mortality. Thus, it should also be possible to assign dollar values to the health benefits. An alternative approach is to estimate threshold values for the health benefits, at which values the benefits would just exceed the costs of the regulation.

12.10 BENEFIT-COST COMPARISONS

Comparisons of health effects with other dollar costs or benefits should be made for comparable durations of disposal. Annual costs, for example, should be compared to the change in health effects attributable to a single year of waste disposal unless the health effects are related to disposal duration in a nonlinear manner. This might happen as a result of saturation of the buffering capacity of the relevant media or because of dependence of health risk on cumulative exposure. In such cases, a realistic duration of disposal should be chosen and the total benefits and costs from this time period compared. If duration of disposal is not identical for benefits and costs, cost-effectiveness estimates will be misleading for decisionmakers.

So that the decisionmaker will have information available in a useful format, the comparison of benefits and costs should be presented in a table as well as being discussed in the text. Both qualitative and quantitative estimates of the benefits and costs should be presented in this table so that the decisionmaker can make his/her own judgment about whether the unquantified benefits and costs are likely to be of sufficient importance as to change the decision he/she might make on the basis of the quantitative estimates alone. The discussion of the table should provide a summary of the implications of the entire analysis for the decisionmaker.

12.11 SENSITIVITY/UNCERTAINTY ANALYSIS

A sensitivity analysis should be performed when there is considerable uncertainty about the values of some of the input parameters. For example, the results of the exposure impacts analysis and the dose-response relationships both are estimated with considerable uncertainty. Sensitivity analysis should be performed for the exposure estimates and the dose-response relationships to provide information about the impact of changes in these parameter values. Full-scale uncertainty analysis should be used only to the extent that the results can be presented in a way that improves the decisionmaker's ability to make informed judgments.

12.12 THE RIA AS A COMPLETE DOCUMENT

The RIA should include a combination of text and appendixes such that the results are reproducible by the reader from the RIA alone. Since the methods used for performing benefit-cost analyses for hazardous waste regulations are not standardized, it is important for all methods used to be described clearly. Equations should be presented in appendixes where appropriate. The results of each stage of the analysis should be presented in tabular form (e.g., waste characterization, release rates, and exposure concentrations) so that the reader can easily follow the steps of the estimation process. References to supporting documents cannot substitute for such detail within the RIA document, even if the bibliographical reference is complete. This is because the supporting document may not be readily obtainable.

The text should avoid lengthy background discussions and should clearly and concisely present the benefit-cost analysis methodology and results. If more detailed discussion seems necessary (e.g., for the derivation of input parameter values), it should occur in an appendix. For example, only the summary of data derived from the industry profile should be included in the text. The industry profile should be presented in an appendix.

In order to facilitate the implementation of these suggested improvements, we recommend that EPA prepare a reference handbook that would complement the RIA Guidelines. Such a handbook might include: a brief but detailed description of all relevant, currently used estimation models and a set of decision rules for choosing among them; for each estimation model, tables of commonly used input parameter values and their sources; and a listing of major data sources that might be useful for hazardous waste RIAs. The handbook also should present suggested refinements to currently used methods, where appropriate. The appendixes for the RCRA Risk-Cost Analysis Model and a more recent report Risk Assessment Methodology for Hazardous Waste Management, provide a convenient starting point for such a reference work.

With the use of such EPA reference documents, the increase in resources needed to achieve all the improvements suggested above may not be large. Some of them involve only clearer presentation of the results of the analysis, including data sources and parameter values used (3), cost-benefit comparisons (9), and overall organization of the report (12). The other suggested improvements might require the use of additional models, but the burden on the preparer of the RIA can be minimized by developing a centralized listing of all such models and central access to the computer programs for them. Even if resource or data limitations prevent additional modeling, all these other suggested improvements can be addressed qualitatively, clearly presenting the methods used in the analysis and how more extensive modeling is likely to affect the results.

SECTION 13

REFERENCES

Crump, K., and Howe, R. B. 1984. "The Multistage Model with a Time-Dependent Dose Pattern: Applications to Carcinogenic Risk Assessment". Risk Analysis 4:163-176.

ICF. 1984. The RCRA Risk Cost Analysis Model: Phase III Report and Appendices. Prepared for Office of Solid Waste, U.S. Environmental Protection Agency. March 1, 1984.

ICF. 1985. Background Document on the Comparative Risk Assessment for RCRA Land Disposal Restrictions. Prepared for Office of Solid Waste, U.S. Environmental Protection Agency. December 27, 1985.

Lawless, Edward W. 1986. Risk Assessment Methodology for Hazardous Waste Management. MRI. Prepared for the Office of Policy, Planning, and Evaluation, U.S. Environmental Protection Agency. Contract No. EQ4C15.

Mauskopf, J., and Curtis-Powell, S. 1985. "Disposal of Hazardous Wastes in Unregulated Landfills: A Health Risk Assessment." Proceedings of the National Conference on Hazardous Wastes and Environmental Emergencies, May 14-16, 1985, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1983. Guidelines for Performing Regulatory Impact Analyses. Office of Policy Planning and Evaluation, Office of Policy Analysis, Economics Analysis Division, Benefits Branch, Washington, DC.

APPENDIX A

RELEASE MODELS CITED

A.1 TO AIR

A.1.1 From RCRA Risk-Cost Analysis Model for Landfills

The Shen (1981) model estimates releases from covered and uncovered waste in landfills; Equation (A.1) applies to uncovered wastes and (A.2) to covered wastes:

$$M_v1 = (1.25)(P_{vp})(w)(l)^{1/2}(M)^{3/4}(x) \cdot 10^{-9}, \text{ and} \qquad (A.1)$$

$$M_v2 = \frac{(0.9)(P_{vp})(M)}{(M)^{-1.2}\ 18.57}(w)(l)(n)^{1.33}\ (x/d) \cdot 10^{-9} \qquad (A.2)$$

where

M_v1 = volatilization rate when wastes are uncovered (kilogram/second [kg/s])

M_v2 = volatilization rate when wastes are covered (kg/s)

P_{vp} = vapor pressure of X (chemical constituent of concern) (millimeters of mercury [mm Hg])

w = width of landfill cell (centimeter [cm])

l = length of landfill cell (cm)

M = molecular weight of constituent X (gram/mole [g/mol])

n = porosity of soil cover (dimensionless)

x = concentration of constituent X in waste, mass fraction (kg/kg)

d = depth of daily cover (cm)

A.1.2 Mackay Model for Organics Release from Road Oiling or Dumping

Organic evaporation rates are determined by the Mackay model (PEDCo, 1984). The calculated rates are valid only for a short time; as evaporation proceeds, oil component concentrations drop, and consequently so do evaporation rates. The following equations represent the Mackay model for calculating evaporation rates:

$$q = KP_i/RT_s \tag{A.3}$$

where

K = mass transfer coefficient (meter/hour [m/h])

P_i = partial vapor pressure (atmospheres [atm])

R = ideal gas constant ($m^3 \bullet$atm/mole-degrees kelvin [mol•K])

T_s = soil surface temperature (K)

q = evaporation rate (mol/$m^2 \bullet$h)

$K = 0.0292\ V^{0.78}\ W^{-0.11}\ SC^{-0.67}$

where

0.0292 = units of conversion factor

V = wind velocity measured at height of 10 m (m/h)

W = road width (m)

SC = Schmidt number (dimensionless)

$P_i = X_i P_i$,

where X_i = mole fraction of oil component i (dimensionless)

P_i = ideal vapor pressure of oil component i (atm).

A.1.3 Tucker Model for Covered Wastes in Landfills (Tucker 1985)

$$\text{Emission rate } (g/m^2/s) = \frac{9.2 \times 10E\text{-}2\ a^{10/3}\ C_s (1.006)^{T-20}}{Dn^2\ M^{1/2}} \tag{A.4}$$

where

$C_s = \frac{PM}{RT_k}$

a = effective porosity of the landfill cover (dimensionless)

T = average annual temperature (degrees Celsius [°C])

D = depth of landfill cover (m)

n = total porosity of cover material (dimensionless)

M = constituent molecular weight

P = vapor pressure (mm Hg)

R = gas constant (mm Hg-liter(L)/K•mol)

T_k = average annual temperature (°K)

A.1.4 Tucker Model for Uncovered Waste in Surface Impoundment (Tucker 1985)

$$q = kC_1 \tag{A.5}$$

where

$$k = \frac{u}{12.2(MW)^{1/2} \ [1.85 \times 10E{+}4 + (1/(H \times 44.6)]}$$

u = wind speed (m/s)
MW = molecular weight (g/mol)
H = Henry's law constant (atm•m^3/mol)
C_1 = constituent concentration in waste (milligram [mg]/L)
q = emission rate (g/m^2/s)

Annualized emission rate:

$$\underset{(g/m^2/s)}{q} = \underset{(g/year[yr])}{\text{solvent quantity}}/\underset{(second[s]/yr)}{31{,}536{,}000}/\underset{(m^2)}{\text{facility area}}$$

A.1.5 From RCRA Risk-Cost Analysis Model for Incinerators

Incinerator outlet gas contains organics and heavy metals. The combustion process incompletely destroys these constituents, and the wet scrubbers installed for air pollution control cannot completely remove them from the combustion gases.

For organic constituents, the model calculates the mass released in the stack gas to the atmosphere using the following expression based on the destruction and removal efficiency (DRE) of 99.993 percent.

$$q_{org.} = 0.00007\ (m_x) \tag{A.6}$$

where

$q_{org.}$ = emission rate for an organic constituent (kg/d)
m_x = input waste stream mass flux of the organic constituent (kg/d).

For metal constituents in the waste streams, the model assumes that 3 percent of the metals contained in the waste feed is emitted as particulate from incinerators with wet scrubbers:

$$q_m = 0.03\ (m_x) \tag{A.7}$$

where

q_m = emission rate for a metal constituent (kg/day[d])
m_x = input waste stream mass flux of the metal constituents (kg/d).

A.1.6 From RCRA Risk-Cost Analysis Model for Waste Piles

The model calculates volatilization from waste piles using a methodology similar to that for landfills (Shen 1981). The equation for determining the rate of volatilization is as follows:

$$M_{vl} = (1.08)(X)(P_{vp})(w)(1)^{1/2}(M)^{3/4} \cdot 10^{-7} \quad (A.8)$$

where

M_{vl} = emission rate (kg/d)
X = mass fraction of X (the chemical constituent of concern) in the waste (kg/kg)
P_{vp} = vapor pressure of X (mm Hg)
w = dimension of pile perpendicular to wind direction (m)
l = dimension of pile parallel to wind direction (m)
M = molecular weight of X (g/mol).

Vehicular traffic, wind erosion, and loading and unloading operations may cause significant releases of particulates. The following equation can be used to estimate total particulate emissions from a waste pile:

$$M_v = (0.0045)(M_{wp})(X)/(PE)^2 \quad (A.9)$$

where

M_v = constituent particulate emission rate (kg/d)
M_{wp} = mass of pile (kg)
X = mass fraction of X (kg/kg)
PE = Thornethwaite's precipitation-evaporation index = 107.

A.1.7 From RCRA Risk-Cost Analysis Model for Surface Impoundments

The Thibodeaux approach (Thibodeaux, Parker, and Heck 1981) determines the release of a constituent to air as a function of its molecular weight, vapor pressure, concentration, and solubility. The equation takes the form:

$$M_v = k_{OA}A_t(X)\ M \quad (A.10)$$

where

M_v = emission rate of constituent (g/s)

k_{OA} = overall mass transfer coefficient ($mol/cm^2 \bullet s$)

A_t = surface impoundment area on top (cm^2)

X = mole fraction of constituent in the liquid phase, (kg/kg)

M = molecular weight of constituent (g/mol).

A.1.8 From RCRA Risk-Cost Analysis Model for Transportation and Spills

Hazardous substances may be released as a result of vehicular accidents and equipment or operator failure. The model assumes that a certain fraction of the hazardous chemical constituents in the released wastes evaporate or volatilize to the air. Of the remainder of any constituent, 70 percent is directed toward surface water and 30 percent toward groundwater.

The fraction of a constituent that evaporates varies for each constituent. It is determined by the following equation (in simplified form):

$$M_{vs} = \frac{85.1 \bullet P_{vp}/P_{water} \bullet X \bullet M^{-1/3}}{1 - (0.031258 \bullet P_{vp}/P_{water} \bullet X)} \quad . \qquad \text{(A.11)}$$

Thus, the volatilization rate, M_{vs}, is a function of molecular diffusivity (expressed in terms of molecular weight, M, and waste properties that are assumed constant), relative volatility (expressed in terms of the vapor pressures of the hazardous constituent and water, P_{vp} and P_{water}, respectively), the mass fraction of the constituent in the waste, X, and an assumed surface area exposed to air for evaporation (included as a constant).

Compared to surface spills from treatment technologies, releases during transportation involve relatively large quantities. Consequently, they are likely to be noticed and to be cleaned up, to some extent, before they reach the environment. The model assumes that 80 percent of a transportation-related release will be cleaned up; i.e., that only 20 percent of the released constituents will reach the environment.

A.2 TO GROUNDWATER

A.2.1 RCRA Risk-Cost Analysis Model for Landfills

The release rates of a chemical constituent into leachate in a landfill at a given time may be calculated by the following equation:

$$M_r = C_o i_r e^{-i_r t/V_n f_m} \qquad (A.12)$$

where

M_r = release rate (mg/yr) of constituent at time t

C_o = initial concentration (mg/m^3) of constituent in leachate (a function of the initial concentration of the constituent in the waste and the solubility of the constituent in water).

i_r = infiltration rate (m^3/yr)

e = constant (2.71828)

t = time (yr)

V_n = waste volume (m^3)

f_m = moisture content at field capacity (assumed to be 55 percent).

This equation represents the solution of the differential equation that approximates the behavior of a well-mixed reactor, where the residence time is equal to the waste volume multiplied by its moisture content and divided by the infiltration rate ($V_n f_m / i_r$).

For example, to calculate the rate of release of cadmium from a landfill cell at time t = 1 year, assuming that the cell contains 415 m^3 of waste and is infiltrated by 250 m^3 of rainwater per year, that the waste has a moisture content of 55 percent, and that the initial concentration of cadmium in the leachate is 3,000 mg/m^3, substitute into the equation as follows:

$$\begin{aligned} M_r &= C_o i_r e^{-i_r (t)/V_n f_m} \\ &= (3000)\ (250)\ (e)^{-(250)(1)/(415)(0.55)} \\ &= (750{,}000)\ (2.71828)^{-1.34} \\ &= 196{,}400 \text{ mg/yr.} \end{aligned} \qquad (A.13)$$

At time t = 6, this equation yields 244 mg/yr.

To compute the cumulative mass leached over a given period, the equation may be integrated:

$$\int_{t_1}^{t_2} a\, e^{-bt} dt = a/b\; e^{-bt_1} - a/b\; e^{-bt_2} \qquad (A.14)$$

where

$t_2 - t_1$ = period of interest
$a = C_o i_r$, a constant with respect to t
$b = i_r/V_n f_m$, a constant with respect to t.

To compute the total mass of cadmium leached in the first year, substitute as follows:

$a = C_o i_r = 750{,}000$
$b = i_r/V_n f_m = 1.34$
$t_1 = 0$
$t_2 = 1$

$$\begin{aligned} \text{Total} &= (750{,}000/1.34)\; e^{-(1.34)(0)} - (750{,}000/1.34)\; e^{-(1.34)(1)} \\ &= 413{,}000 \text{ mg} \end{aligned} \qquad (A.15)$$

During the sixth year ($t_1 = 5$, $t_2 = 6$), the result is 509 mg.

The examples (Straub 1982) indicate that the quantity of leached constituent decreases dramatically over time, a result confirmed by field test results.

To determine the constituent concentration in the leachate released from a landfill, the cumulative mass of the constituent in the leachate, as calculated by Equation (A.14) is divided by the total leachate quantity formed (see below).

The total leachate quantity formed is calculated in Equation (A.16):

$$M_l = M_{fl} + M_{ai} \qquad (A.16)$$

where

M_l = total leachate quantity
M_{fl} = mass of free liquids (if any)
M_{ai} = mass of infiltrated rainfall available to form leachate.

The total leachate quantity is greatest during operations, when one landfill cell is open to the elements. After closure of the landfill, leachate formation due to rainwater infiltration is limited by the landfill cover.

Containerized wastes do not contribute to the formation of leachate as long as the containers are intact. The model assumes that containers corrode after 5 years, thereafter releasing free liquids and exposing the waste to infiltrating rainwater.

A.2.2 Liner Location Model Release Assumptions from Lined Landfill

Solubility determines the mass released per year of each constituent that land disposal facilities release following a liner failure. Mass release rate is the product of flow passing through the liner and the aqueous solubility of the constituent--that is, the submodel assumes that leachate is saturated with the constituent. Several standard secondary references contain the solubilities of organic constituents. The solubilities of inorganics are generally much more variable, depending on pH, ligands present, oxidation/reduction potential, and other factors. However, the model assumes a constant solubility value for each inorganic constituent. Furthermore, the entire quantity of waste deposited into the facility is assumed to be available to leave the facility by volatilizing or by leaching after facility failure.

The simulation model was designed to incorporate mass balance techniques such that the flow of liquid into and from the disposal system could be estimated at the same time that the proportion of facilities that fail is determined. In this manner, the liquid balance and fault-tree analyses are considered to be parallel.

The following steps are implemented for a given iteration and a given benchmark period in the simulation model:

- Specify net infiltration and multiply by duration of time (up to benchmark period) and area of facility.
- Compare benchmark time to time of closure.
- If benchmark is less than time of closure (i.e., <20 years) evaluate appropriate fault-trees to determine whether infiltration enters active cell due to inadequate run-on control measures (if so add 1/20 of net infiltration volume to budget).

- Subtract fraction of infiltration due to runoff (95 percent if cover intact, 60 percent if cover cracked).

- Subtract fraction of remaining infiltration to represent liquid captured by drainage collection system (99 percent* for intact covers, 79 percent for breached covers).

- Evaluate fault-trees to determine if other inputs to hydrologic budget occur (groundwater fluctuation, flooding, etc.).

- Evaluate fault-trees to determine if liner failure has occurred.

- Subtract fraction of total remaining budget to represent leachate captured by leachate collection systems (varies from 99 percent for intact liners to 40 to 75 percent, depending on liner permeability for breached liners).*

- If benchmark time is greater than the postcare period (>50 years) no leachate is collected in retrieval systems.

- Subtract volume of leachate representing permanent storage in clay liner.

- If remaining leachate budget is greater than zero, then failure has occurred and leachate volume is equal to leachate budget.

These steps are repeated for each benchmark period and for all iterations in a simulation run. Average leachate release volumes are calculated for each benchmark period.

For example, the duration of infiltration through failed covers and flow through containment liners are tied to the times at which these components fail. For example, if a cover fails at year 40, and a simulation is run for a benchmark period of 50 years, then the total flow through the cover would be given by the following:

Total volume = 20 x flow rate during preclosure +
(40-20) x flow through intact cover +
(50-40) x flow through breached cover.

where the start of the postclosure period is at year 20. Different mechanisms may result in cover failure at different times. In such cases the one that occurs first is used to define the initiation of failure. Different runoff and drainage collection efficiencies would be used to describe flow through the intact and breached covers. These values are based upon EPA guidance documents describing the design of disposal facility covers and theoretical analyses of collection system efficiencies by Kmet et al. (1981).

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*These percentages are equal to 100-percent efficiency of the collection system.

A.3 REFERENCES

Kmet, P., K. J. Quinn, and C. Slavik. 1981. Analysis of design parameters affecting the collection efficiency of clay lined landfills. Fourth Annual Madison Conference of Applied Research and Practice on Municipal and Industrial Waste, Madison, Wisconsin, September 28-30.

PEDCo Environmental, Inc. 1984. Evaluation of Health and Environmental Problems Associated with the Use of Waste Oil as a Dust Suppressant. Final draft report prepared for Office of Solid Waste, U.S. Environmental Protection Agency.

Shen, Thomas T. 1981. Estimating hazardous air emissions from disposal sites, Pollution Engineering, 13, (7):31-34.

Straub, W. A. 1982. Models of landfill leaching: moisture flow and inorganic strength, and Models of landfill leaching: organic strength. ASCE Journal, 108, (EE2):231-268.

Thibodeaux, L. J., David G. Parker, and Howell H. Heck. 1981. Measurement of Volatile Chemical Emissions from Wastewater Basins. U.S. Environmental Protection Agency, Industrial Environmental Research Laboratory.

Tucker, William. 1985. Exposure to Airborne Contaminants Release from Land Disposal Facilities--A Proposed Methodology. Environmental Science and Engineering.

Weber, Walter J., Jr. 1972. Physicochemical Processes for Water Quality Control. Wiley Interscience. p. 42.

APPENDIX B

TRANSPORT MODELS CITED

B.1 IN AIR

B.1.1 Hanna-Gifford Area Source Dispersion Model

The Hanna-Gifford Model was developed by the Air Resource Atmospheric Turbulence and Diffusion Laboratory in Oak Ridge, Tennessee. This simple but realistic dispersion model can estimate pollutant concentrations resulting from area source emissions in urban areas. It performs best in large urban-wide applications, especially in the modeling of low-level sources that are distributed fairly evenly across such an area.

B.1.2 Gaussian Line Source Dispersion Model

The following equation (Sutton 1932) calculates the concentrations for downwind Gaussian distributions of line source emissions:

$$C = \frac{2}{2\pi\sigma_z V} Re \qquad (B.1)$$

where

C = concentration of constituent at distance X from the point of release (mg/m^3)

Re = line source release rate of constituent (mg/d)

σ_z = dispersion in vertical direction (m)

V = mean wind speed (m/d).

B.1.3 Turner and Canady Point Source Dispersion Model

The following equation (Turner 1970) calculates the concentrations for downwind Gaussian distributions of two-dimensional, point source emissions:

$$C = \frac{Re}{\pi\sigma_y \sigma_z V} \qquad (B.2)$$

where

C = concentration of constituent at distance X from the point of release (mg/m^3)

Re = point source release rate of constituent (mg/d)

σ_y = dispersion in lateral direction (m)

σ_z = dispersion in vertical direction (m)

V = mean wind speed (m/d).

It is important to acknowledge that estimating atmospheric concentrations of point source emissions of chemicals using this equation introduces a great deal of uncertainty, although it appears to be the most accurate way to obtain engineering estimates of ground-level pollution concentrations (Canady 1973). The uncertainty is due to wide variations in geographical and meteorological conditions such as terrain, wind speed, turbulence, and temperature; these conditions can change drastically in a short period of time.

B.1.4 Industrial Source Complex Long-term Model

The Industrial Source Complex (ISC) long-term model was developed by Bowers et al. (1980) for the Source Receptor Analysis Branch, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency. At the direction of the Office of Toxic Substances, EPA, ISC was the first model implemented in the General software Atmospheric exposure Modeling System (GAMS),* which is an integrated atmospheric modeling subsystem of GEMS.

ISC may be used as a screening or detailed level model to estimate atmospheric concentration or deposition values. It is also possible to estimate populations exposed to various levels of pollutant concentration and the population exposure through the integration of ISC within GAMS.

ISC combines and enhances various dispersion model algorithms into a computer program that can be used to assess the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. For plumes comprised of particulates with appreciable gravitational settling velocities, ISC accounts for the effects on ambient particulate concentrations of gravitational settling and dry deposition. Alternately, ISC can be used to calculate dry deposition. The ISC long-term model is a sector-averaged model that extends and combines basic features of the Air Quality Display Model (AQDM) and the Climatological Dispersion Model (CDM). The long-term model uses statistical wind summaries to calculate annual ground-level concentration or deposition values.

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*Provisional name.

ISC is currently implemented using a polar coordinate scheme for calculation of pollutant concentrations. GAMS retrieves population distributions on the same coordinates scheme to estimate population exposed and annual population exposure.

ISC accepts the following source types: stack, area, and volume. The volume source option is also used to simulate line sources. The steady-state Gaussian plume equation for a continuous source is used to calculate ground-level concentrations for stack and volume sources. The area source equation in the ISC Model programs is based on the equation for a continuous and finite crosswind line source. Procedures suggested by Huber and Snyder (1976) and Huber (1977) are used to evaluate the effects of the aerodynamic wakes and eddies formed by buildings and other structures on plume dispersion. A wind-profile exponent law is used to adjust the observed mean wind speed from the measurement height to the emission height for the plume rise and concentration calculations. The Pasquill-Gifford curves (Turner 1970) are used to calculate lateral (σ_y) and vertical (σ_z) plume spread. ISC also has rural and urban options.

B.1.5 EPA Screening Model for Short-Term Exposures

This model is used to obtain maximum ground-level concentrations for 1- to 24-h averaging times for comparison with standards for short-term (acute) exposure to hazardous air pollutants.

All of the procedures in this model, with the partial exception of receptors on elevated terrain, are based upon the bi-variate Gaussian dispersion model assumptions described in the Workbook on Atmospheric Dispersion Estimates (Turner 1970). The scope of the procedure is confined to point sources, plume heights of 10 to 300 m, and concentrations averaging 1 to 24 h.

The maximum 1-h ground-level concentration due to emissions from the stack in question is computed as a function of plume height, ambient air concentration, and emission rate. This 1-h value may be multiplied by an appropriate factor to obtain concentrations for averaging times greater than 1 h.

B.2 IN GROUNDWATER

B.2.1 Wilson and Miller Steady-State Release Model (Saturated Flow)

The model predicts constituent concentrations in groundwater assuming that constituent releases are continually flowing into a groundwater formation underlying the release source. The equation used describes a steady-state, two-dimensional plume of pollution developing downstream of the source as a function of groundwater seepage, velocity, dispersion, thickness of groundwater formation, effective porosity, retardation due to adsorption on soil, and the natural decay rate of the chemical. The equation used is (Wilson and Miller 1978):

$$C = \frac{Re \exp\left[XV(1 - \sqrt{\rho})/2D_x\right]}{2\,\pi nm(D_x D_y)^{0.5}} \left(\frac{\pi D_x}{X\, V\sqrt{\rho}}\right)^{0.5} \tag{B.3}$$

where

C = concentration of constituent at distance X from the point of release (mg/L)

Re = release rate of constituent to groundwater (mg/d)

n = effective porosity of the groundwater formation (dimensionless)

m = vertical thickness of groundwater layer (m)

D_x = longitudinal dispersion coefficient (m^2/d)

D_y = transverse dispersion coefficient (m^2/d)

V = groundwater seepage velocity in the direction of flow (m/d)

X = distance from release point (m)

$\rho = 1 + \frac{4D_x R_d \lambda}{y^2}$ (dimensionless)

R_d = chemical-specific retardation factor (dimensionless)

λ = chemical-specific decay rate (d^{-1}).

The model uses this equation, which assumes a balance between the rate at which pollution disperses and the rate of release, to calculate a single steady-state concentration to represent the concentration of a constituent in groundwater. The model assumes that the drinking water supply of the entire population within a 1-kilometer radius of the point of release contains the constituent in this concentration, much as if that population's drinking water supply was obtained from a single well drilled 1-kilometer downgradient from the source of the release. The equation does not account for how long it will take the steady-state concentration to develop at the 1-kilometer well even though this process could be lengthy because of the relatively slow movement of the groundwater; releases of the most hazardous constituents are assumed to have been occurring long enough for steady-state concentrations to be reached.

Some of the variables in the equation have values specific to environmental setting while others are chemical-specific. Other variables in the equation are constituent-specific, such as decay rate and retardation factor. A constituent's decay rate is expressed as a half-life in groundwater; many constituents in used oil do not decay significantly in groundwater; i.e., they are persistent. The retardation factor (R_d) measures the effect that sorption processes in the soil have on a chemical's mobility. For organic constituents, retardation is primarily a function of the soil's organic adsorption properties and, for inorganic constituents, retardation mechanisms are a combination of sorption processes that depend not only on the soil type and soil conditions (e.g., pH, clay content, and ionic strength) but also on absorbate concentration.

B.2.2 From RCRA Risk-Cost Analysis Model for Surface Impoundments (Saturated Flow)

The model uses Darcy's equation for saturated flow to estimate this flow (Sowers 1970):

$$Q = k_s \, I \, A_b \, (\rho_w) \qquad \text{(B.4)}$$

where

Q = flow through the base of the surface impoundment (kg/yr)
k_s = saturated permeability coefficient (m/yr)
I = hydraulic gradient (dimensionless)

A_b = area of base of surface impoundment (m^2)

ρ_w = density of water (1,000 kg/m^3).

B.2.3 McWhorter and Nelson Wetting Front Model for Unsaturated Flow

The modified McWhorter-Nelson (1979) equation is:

$$t = (L/q)\ (n - \theta_r)\ (q/K)^{x/(2+3x)} (Rd) \qquad (B.5)$$

where

t = constituent travel time (yr)

L = unsaturated zone thickness (m)

q = leakage rate (Darcian flux) at liner (m/yr)

n = soil porosity (dimensionless)

θ_r = initial soil moisture content, assumed to be at field capacity (dimensionless)

K = saturated hydraulic conductivity (m/yr)

x = pore-size distribution index (dimensionless)

Rd = constituent retardation factor (dimensionless).

The leakage rate, q, is calculated by dividing the predicted leachate release rate (m^3/yr) by facility surface area (m^2). Rd is constituent-specific.

B.2.3 Random Walk Particle Tracking Model for Saturated Flow

To simulate up to 200 years of mass transport through multilayered groundwater flow fields in this project, the Random-Walk model of Prickett, Naymik, and Lonnquist (1981) can be used. This particle-tracking computer code, developed by these authors at the Illionois State Water Survey, is well documented and has been tested against several analytical solutions.

The Random-Walk code begins a simulation by introducing a suitable number of particles representing a finite amount of mass into the velocity field. Particles are introduced at random over a specified period of time called a "time step." Transport of these particles through the flow field is divided into two stages. In the first stage, called the "advective stage," the particles are moved in the direction of groundwater flow in sequential time steps. The distance moved in each time step is equal to the velocity multiplied by the duration of the time step. At the end of each time step, the particles are again moved to simulate the dispersion process. In this second "dispersive stage," the model assumes that dispersion is a random process that would follow a normal distribution function. Each particle is given a random dispersive displacement based on the value for the longitudinal and transverse dispersion coefficients, the distance moved in the advective stage, and a random number between zero and one. The distance moved in the advective stage is added to the distance moved in the dispersive stage and the new coordinates for each particle are stored at the end of each time step.

The mobility-determining retardation factors associated with three contaminant mobility classes were applied to all layers uniformly in a scenario simulation. The retardation factors are used to transform the groundwater velocity vectors into contaminant velocity vectors at any point within the flow field. The retardation factors also reduce the value of the disperson coefficients, which are directly proportional to dispersivity and contaminant velocity.

B.2.4 PLUME Contaminant Transport Model for Saturated Flow

This model (Van der Heijde 1983) provides an analytic solution to the two-dimensional groundwater transport equation and is applicable to transport in porous, isotrophic media. The PLUME model is not designed to handle the complex hydrogeological conditions that occur at most actual sites. As such, the model does not provide accurate estimates of contaminant transport in fractured or stratified geologic formations. Nor is it able to account for changes in flow direction or velocity induced by actions such as the pumping of wells. However, in the absence of detailed hydrologic data for sites where solvents are land-disposed, the PLUME model provides acceptable pollutant concentration estimates for the purposes of risk assessment.

To run the PLUME model, the user must specify the groundwater velocity, effective soil porosity, aquifer depth, dispersivity, landfill width, and the annual release quantity and duration of these releases. For pollutants that degrade in the aquifer, a half-life also may be specified. In addition, the user can specify a retardation coefficient indicating how transport of the contaminant is slowed due to its attenuation by organic materials in the subsurface media.

B.3 SURFACE WATER

B.3.1 Loucks, Stedinger, and Haith Surface Water Transport Model

The model uses a simplified equation to represent the behavior of a chemical released to surface water. A one-dimensional, exponential decay equation (Loucks, Stedinger, and Haith 1981) that assumes complete mixing at the point of discharge and natural aquatic decay rates is used:

$$C = C_o \exp - \frac{K_{sw} X}{V} \tag{B.6}$$

where

C = concentration of constituent C at distance X from the point of release (mg/L)

C_o = initial constituent concentration in the surface water due to the release of the constituent (mg/L)

K_{sw} = overall decay rate coefficient of the chemical in surface water (d^{-1})

X = distance from the point of release (m)

V = constant downstream velocity of the water body (m/d).

Constant stream flow, small and negligible dispersion, constant cross-sectional area, first-order kinetics, and steady-state conditions are also assumed for the one-dimensional river or stream system.

This equation provides a reasonably accurate description of the behavior of a chemical in an average river system when released in small amounts and present at extremely low concentrations.

Although the equation is relatively simple, the underlying factors that govern the values of its parameters are complex. Once a chemical is released into surface water, its behavior is influenced by both environmental factors and chemical-specific factors: the flow, Q, of surface water dilutes the released constituent to some initial concentration level, C_o; the downstream velocity, V, of the water body determines the time it will take for the chemical to reach the exposure site at distance X, the chemical degradation rate coefficient (K) is constituent-specific and depends on the strength of the chemical's bonds and their susceptibility to various natural and physical chemical processes.

The initial concentration, C_o, of a chemical is that concentration attained when the chemical mixes with the surface water. Instantaneous mixing is assumed (this assumption is more reasonable for fast-moving, highly turbulent rivers than for slower moving river systems). This concentration, C_o, is calculated by dividing the mass of constituent released per day by the average daily flow, Q, assumed to be 10^9 L/d (low assimilative capacity).

B.4 REFERENCES

Bowers, J. F., J. R. Byorklund, and C. S. Cheney. 1980. Industrial Source Complex (ISC) Dispersion Model User's Guide, Volume 1. PB80-133044, Research Triangle Park, NC: Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency.

Canady, G. T. 1973. Turbulent Diffusion in the Environment. Dordrecht: D. Reidel Publishing Company, p. 75.

Huber, A. H., and W. H. Snyder. 1976. Building wake effects on short stack effluents. Reprint Volume for the Third Symposium on Atmospheric Diffusion and Air Quality. Boston, MA: American Meteorological Society.

Huber, A. H. 1977. Incorporating building/terrain wake effects on stack effluents. Reprint Volume for the Joint Conference on Applications of Air Pollution Meteorology. Boston, MA: American Meteorological Society.

Loucks, D. P., J. R. Stedinger, and D. A. Haith. 1981. Water Resource Systems Planning and Analysis. Englewood Cliffs, NJ: Prentice-Hall, Inc., pp. 435-437.

McWhorter and Nelson. 1979. Unsaturated Flow Beneath Tailings Impoundments. J. Geotech. Eng. Div., ASCE GJ (11):1317-1334.

Prickett, T. A., Naynik, T. C., and Longquist, C. G. 1981. A "Random Walk" Solute Transport Model for Selected Groundwater Quality Evaluations. Bulletin #65 Illinois State Water Survey.

Sowers, G. B. 1970. Introductory Soil Mechanics and Foundations, 3rd edition. New York: MacMillan Company, pp. 91-94.

Sutton, O. G. 1932. A Theory of Eddy Diffusion in the Atmosphere. Proceedings of the Royal Society of London, 135:154.

Turner, B. D. 1970. Workbook of Atmospheric Dispersion Estimates. PB-191482, Cincinnati: U.S. Department of Health, Education, and Welfare.

Van der Heijde. 1983. [Incomplete reference in Solvents RIA.]

Wilson, J. L., and P. J. Miller. 1978. Two Dimensional Plume in Uniform Ground Water Flow. Journal Hyd. Div., ASCE, AY4:503-514.